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ABSTRACT

Presented is a set of learning modules intended for teaching science to students in grades eleven and twelve. Each module incorporates problem solving using the scientific viewpoint and emphasizing the interface between science and society. The fifteen modules presented include the following topics: group dynamics; the value of science; a puzzle entitled "The Lebon Prize"; a role playing experience called "Dr. Stuffy"; nuclear power; the Herzberg lecture on boundaries of knowledge; lifeboat ethics; early science and the nature of matter; Plato, Aristotle and Ptolemy; Copernicus; Galileo; Newton; relativity; twenty ways the world could end; and a theory today. Each module is intended to last approximately one hour. An evaluation of the project is given at the back of the text. The appendices contain a preference survey and a student opinionnaire. (SA)

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Saskatchewan School Trustees Association

SE 029 407

SENIOR SCIENCE

ENRICHMENT MODULES

by

Fedorak Johnson Seneshen

Walter Murray Collegiate

Saskatoon 1978

S.S.T.A. Research Centre Report No. 58

A report with recommendations prepared under the auspices of the Saskatchewan School Trustees Association Research Centre

November, 1978

Note: The opinions expressed in this report are those of the authors and may or may not be in agreement with SSTA officers or trustees, but are offered as being worthy of consideration by those responsible for making decisions.

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An SSTA Research Project

in Curriculum Development

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SENIOR SCIENCE

ENRICHMENT MODULES

Walter Murray Collegiate

1905 Preston Avenue

Saskatoon Saskatchewan

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THE VALUE OF SCIENCE by Richard Feynman. Published by Holt, Rinehart, and Winston Inc., Toronto, in Harvard Project Physics.

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HERZBERG LECTURE Published in the Transactions of the Royal Society of Canada (Vol. XII), 1974.

LIFE BOAT ETHICS by Garrett Hardin and Janet Besecker. Published in Psychology Today, September, 1974.

GALILEO Fragments published by Holt, Rinehart, and Winston Inc., Toronto, in Harvard Project Physics.

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Allen Fedorak

Donald Johnson

Saskatoon, July 1978

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INTRODUCTION

Our intent in this innovative project -- Senior Science Enrichment Modules -- was to develop fifteen modules of work to aid in the teaching of the full course content of the senior science as outlined in the Department of Education guides for Saskatchewan Schools. For example, in the Chemistry Guide reference is made to an entirely new dimension in science teaching -- dimension B, the cultural and social aspects of science. Similarly, in physics fifteen percent of the course content is specifically to be spent upon enrichment topics.

Clearly, it is the intent of the senior science curriculum committees, at the present time, to place a new and important emphasis on the interface between science and society.

The fifteen modules of work, each of approximately one hour duration, were especially designed for students enrolled in grades eleven and twelve senior science classes in Saskatchewan high schools.

Within the modules of work the emphasis was placed on the interdependence of knowledge and action through studying the inter-relationships among man, science, and society. One of the more recent trends in education has been the formal use, by students, of topics concerning the clarification of values; this process helps the student to rationalize decisions upon current real-life issues. The practical utility of science and technology is fairly obvious to most students participating in our present consumer society, however, it is not potently obvious that a definite science-oriented viewpoint may be applied in many life situations. The usefulness of a scientific viewpoint in trying to solve everyday problems has tried to be incorporated into each module of work.

The following generalized goals may be explicitly stated:

1. Fifteen percent of the course is required for either enrichment or dimension B topics.
2. The inter-relationships between man, science, and society should be illustrated.
3. Value clarifications should be incorporated into the modules.
4. Emphasis should be placed upon science-oriented procedures used to solve everyday problems.
5. The historial approach should be used, wherever possible, to show the growth of scientific ideas.
6. The content, and evaluative, base of science should be broadened and made more relevant.

The modules are scheduled to occupy the students concerned for a one-hour time span; and since there are fifteen modules of work, the program may conveniently be attached to the already existing senior science programs. Perhaps, their main feature, at this time, is to provide other educators with a model which they could freely adapt to their own particular teaching situation.

The first module is on GROUP DYNAMICS, and since all the students are expected to work in small groups throughout the entire program, it was felt worthwhile to include a section of work informing them about the relations which occur within the group. After introducing the program with the GROUP DYNAMICS module, the remaining fourteen modules may be presented in any order the teacher wishes.

The following outline presents a brief glimpse at each of the remaining modules:

THE VALUE OF SCIENCE - an article by Feynman is followed by discussion and questions.

THE LEBON PRIZE - a scientific research simulation game. The students, indirectly, learn about the scientific community.

DR. STUFFY - presents the students with a unique research finding, and they have to decide its possible future.

THE NUCLEAR DEBATE - permits students to become involved with the issues of a current Saskatchewan science - related problem.

THE HERZBERG LECTURE - the students are given information upon the limitations of present-day science by a noted Canadian scientist.

LIFE BOAT ETHICS - a simulation game which forces students to choose and select, under rather severe conditions, and clarify their own particular set of values.

EARLY SCIENCE - considers the cradle of science activity in Greece, and allows students to discuss the early atomic and plenum theories of matter.

PLATO ARISTOTLE PTOLEMY - gives the students insight into the philosophy of science, and presents them with the first successful mathematical model of the universe.

COPERNICUS - lets the students experiment with simple astronomy.

GALILEO - forces students to consider the implications of change, and considers Galileo the man-scientist.

NEWTON - the students deal with the scientific and mathematical work of Principia.

RELATIVITY - considers the importance of modern scientific ideas upon the structure of societies thinking. Students deal with the simple mathematical principles.

TWENTY WAYS THE WORLD COULD END - allows students to react to an article by a well-known science writer,

A THEORY TODAY - presents students with the theory formulated by Piaget. They then have to decide upon their criteria for its validity.

Each module attempts to be self-contained. That is each consists of a page (or more) of particular teaching hints most helpful for a first time user; some specific time scheduling for the pace of the lesson; audio-visual materials which may be used during the lesson, and where to obtain them; particular, relevant readings; reference material; and, student worksheets.

The final phase of the report focusses upon Evaluation. Essentially, a modified form of Stufflebeam's CIPP Model was utilized covering content, input, and product evaluative elements. Our evaluation techniques attempted to correct for both internal and external consistency; and, two formal instruments evaluated the finished program. Finally, an objectives grid was used to satisfy the criteria of validity. All statistical procedures used in the evaluation were normal and straightforward, and may be found in any standard textbook.

Senior Science

Enrichment Modules

GROUP DYNAMICS

TEACHING HINTS
FOR
GROUP DYNAMICS

1. This module should take approximately one hour. It may be used with Grade XI or XII students at the beginning of the course.

2. It is suggested that only one module per week be used for the course on the semester system. Thus there is enough material for fifteen weeks.

3. The "Who Am I?" section should take about fifteen minutes.

4. The Group Problem should take about twenty minutes.

5. The Group Role discussion should mention the following:

Leader	Silent member
Domineering personality	Mrs. Helpful
Yes-man	Grumpy
Clown	Active Participant

Clearly, the list can be extended to suit your own situation.

6. Identifying goals should take about twenty minutes.

7. The teacher should insist upon having some work completed by the student which will be handed in for grading.

8. Film: "Anatomy of a Group." A thirty-minute film on group dynamics, #301.1 SaskMedia.

STUDENT WORKSHEET

ON

GROUP DYNAMICS

1. Who Am I?

The class is divided into groups of approximately six students. Within your group, get with one other student (perhaps, two, if necessary). Talk together about each other for five minutes, and after this time you will be expected to introduce the other person to the group. In your introduction, you will assume the identity of the other person.

Notes on other person:

2. Group Problem

Solve the following problem as a group.

DATES FOR THE SOCK HOP

Ernie, Fred, Guy, and Hank and their dates arranged to go to the Sock Hop together. Their dates were Anne, Bessie, Clara, and Doris, but not respectively. The group exchanged dances and at one time during the dance, the following couples were seen dancing together:

1. Bessie is dancing with Ernie.
2. Anne is dancing with Clara's date.
3. Doris is dancing with Anne's date.
4. Fred is dancing with Guy's date.
5. Guy is dancing with Ernie's date.

You are to resolve all these mixed up pairs and tell who dated who.

3. Notes on Class Discussion: Group Roles

4. Identifying Roles

In your group try to match up the group roles discussed above and members of your group. Be diplomatic!

Write a brief description of your ideal role.

Senior Science

Enrichment Modules

THE VALUE OF SCIENCE

TEACHING HINTS

FOR

THE VALUE OF SCIENCE

1. This module should take approximately one hour, or two if film is used.

2. A good introduction is to show the film "Knowledge or Certainty" (50 mins.), SaskMedia.

3. Students should be encouraged to read the article, and then freely discuss it in their groups.

4. Students should be given the final page (concluding paragraph) AFTER their discussion.

5. Students should hand in work for evaluation.

STUDENT WORKSHEET

ON

THE VALUE OF SCIENCE

Please read the article written by the Nobel prize winning scientist, Dr. Richard Feynman. The following questions may help you to focus your reading--do discuss your answers with others in your group:

1. In what way does Feynman suggest that he is dumb?

2. Write the Buddist proverb.

3. Is science a type of religious experience for Feynman? Explain.

4. What does Feynman say about the human brain or mind? Does it stay the same?

5. Children and ideas . . . . What is Feynman suggesting?

6. How is scientific knowledge defined by Feynman?

7. The end of the article has been omitted. With help from others in the group, write a concluding paragraph for the article.

8. As a final conclusion to this module, read Feynman's concluding paragraph.

OUR RESPONSIBILITY AS SCIENTISTS

We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. There are tens of thousands of years in the future. Our responsibility is to do what we can, learn what we can, improve the solutions and pass them on. It is our responsibility to leave the men of the future a free hand. In the impetuous youth of humanity, we can make grave errors that can stunt our growth for a long time. This we will do if we say we have the answers now, so young and ignorant; if we suppress all discussion, all criticism, saying, "This is it, boys, man is saved!" and thus doom man for a long time to the chains of authority, confined to the limits of our present imagination. It has been done so many times before.

It is our responsibility as scientists, knowing the great progress and great value of a satisfactory philosophy of ignorance, the great progress that is the fruit of freedom of thought, to proclaim the value of this freedom to teach how doubt is not to be feared but welcomed and discussed, and to demand this freedom as our duty to all coming generations.

Senior Science

Enrichment Modules

THE VALUE OF SCIENCE

by

*Richard P. Feynman

*An outstanding contemporary theoretical physicist reminisces informally about science and its role in society. Feynman stresses the importance in science, and elsewhere, of admitting that one does not know all the answers.

THE VALUE OF SCIENCE

From time to time, people suggest to me that scientists ought to give more consideration to social problems--especially that they should be more responsible in considering the impact of science upon society. This same suggestion must be made to many other scientists, and it seems to be generally believed that if the scientist would only look at these very difficult social problems and not spend so much time fooling with the less vital scientific ones, great success would come of it.

It seems to me that we do think about these problems from time to time, but we don't put full-time effort into them--the reason being that we know we don't have any magic formula for solving problems, that social problems are very much harder than scientific ones, and that we usually don't get anywhere when we do think about them.

I believe that a scientist looking at nonscientific problems is just as dumb as the next guy--and when he talks about a nonscientific matter, he will sound as naive as anyone untrained in the matter. Since the question of the value of science is not a scientific subject, this discussion is dedicated to proving my point--by example.

The first way in which science is of value is familiar to everyone. It is that scientific knowledge enables us to do all kinds of things and to make all kinds of things. Of course, if we make good things, it is not only to the credit of science; it is also to the credit of the moral choice which led us to good work. Scientific knowledge is an enabling power to do either good or bad--but it does not carry instructions on how to use it. Such power has evident value--even though the power may be negated by what one does.

I learned a way of expressing this common human problem on a trip to Honolulu. In a Buddhist temple there, the man in charge explained a little bit about the buddhist religion for tourists, and then ended his talk by telling them he had something to say to them that they would never forget--and I have never forgotten it. It was a proverb of the Buddhist religion:

> To every man is given the key to the gates of heaven;
> the same key opens the gates of hell.

What then, is the value of the key to heaven? It is true that if we lack clear instructions that determine which is the gate to heaven and which the gate to hell, the key may be a dangerous object to use, but it obviously has value. How can we enter heaven without it?

The instructions, also, would be of no value without the key. So it is evident that, in spite of the fact that science could produce enormous horror in the world, it is of value because it can produce something.

Another value of science is the fun called intellectual enjoyment which some people get from reading and learning and thinking about it, and which others get from working in it. This is a very real and important point and one which is not considered enough by those who tell us it is our social responsibility to reflect on the impact of science on society.

Is this mere personal enjoyment of value to society as a whole? No! But it is also a responsibility to consider the value of society itself. Is it, in the last analysis, to arrange things so that people can enjoy things? If so, the enjoyment of science is as important as anything else.

But I would like not to underestimate the value of the world view which is the result of scientific effort. We have been led to imagine all sorts of things infinitely more marvelous than the imaginings of poets and dreamers of the past. It shows that the imagination of nature is far, far greater than the imagination of man. For instance, how much more remarkable it is for us all to be stuck--half of us upside down--by a mysterious attraction, to a spinning ball that has been swinging in space for billions of years, than to be carried on the back of an elephant supported on a tortoise swimming in a bottomless sea.

I have thought about these things so many times alone that I hope you will excuse me if I remind you of some thoughts that I am sure you have all had--or this type of thought--which no one could ever have had in the past because people then didn't have the information we have about the world today.

For instance, I stand at the seashore, alone, and start to think. There are the rushing waves . . . mountains of molecules, each stupidly minding its own business . . . trillions apart . . . yet forming white surf in unison.

Ages on ages . . . before any eyes could see . . . year after year . . . thunderously pounding the shore as now. For whom, for what? . . . on a dead planet, with no life to entertain.

Never at rest . . . tortured by energy . . . wasted prodigiously by the sun . . . poured into space. A mite makes the sea roar.

Deep in the sea, all molecules repeat the patterns of one another till complex new ones are formed. They make others like themselves . . . and a new dance starts.

Growing in size and complexity . . . living things, masses of atoms, DNA, protein . . . dancing a pattern ever more intricate.

Out of the cradle onto the dry land . . . here it is standing . . . atoms with consciousness . . . matter with curiosity.

Stands at the sea . . . wonders at wondering . . . a universe of atoms . . . an atom in the universe.

THE GRAND ADVENTURE

The same thrill, the same awe and mystery, come again and again when we look at any problem deeply enough. With more knowledge comes deeper, more wonderful mystery, luring one on to penetrate deeper still. Never concerned that the answer may prove disappointing, but with pleasure and confidence we turn over each new stone to find unimagined strangeness leading on to more wonderful questions and mysteries--certainly a grand adventure!

It is true that few unscientific people have this particular type of religious experience. Our poets do not write about it; our artists do not try to portray this remarkable thing. I don't know why. Is nobody inspired by our present picture of the universe? The value of science remains unsung by singers, so you are reduced to hearing--not a song or a poem, but an evening lecture about it. This is not yet a scientific age.

Perhaps one of the reasons is that you have to know how to read the music. For instance, the scientific article says, perhaps, something like this: "The radioactive phosphorus content of the cerebrum of the rat decreases to one-half in a period of two weeks." Now, what does that mean?

It means that phosphorus that is in the brain of a rat (and also in mine and yours) is not the same phosphorus as it was two weeks ago, but that all of the atoms that are in the brain are being replaced, and the ones that were there before have gone away.

So what is this mind, what are these atoms with consciousness? Last week's potatoes! That is what now can remember what was going on in my mind a year ago--a mind which has long ago been replaced.

That is what it means when one discovers how long it takes for the atoms of the brain to be replaced by other atoms, to note that the thing which I call my individuality is only a pattern or dance. The atoms come into my brain, dance a dance, then go out; always new atoms but always doing the same dance, remembering what the dance was yesterday.

THE REMARKABLE IDEA

When we read about this in the newspaper, it says, "The scientist says that this discovery may have importance in the cure of cancer." The paper is only interested in the use of the idea, not the idea itself. Hardly anyone can understand the importance of an idea, it is so remarkable. Except that, possibly, some children catch on. And when a child catches on to an idea like that, we have a scientist. These ideas do filter down (in spite of all the conversation about TV replacing thinking), and lots of kids get the spirit--and when they have the spirit you have a scientist. It's too late for them to get the spirit when they are in our universities, so we must attempt to explain these ideas to children.

I would now like to turn to a third value that science has. It is a little more indirect, but not much. The scientist has a lot of experience with ignorance and doubt and uncertainty, and this experience is of very great importance, I think. When a scientist doesn't know the answer to a problem, he is ignorant. When he has a hunch as to what the result is, he is uncertain. And when he is pretty darn sure of what the result is going to be, he is in some doubt. We have found it of paramount importance that in order to progress we must recognize the ignorance and leave room for doubt. Scientific knowledge is a body of statements of varying degrees of certainty--some most unsure, some nearly sure, none absolutely certain.

Now, we scientists are used to this, and we take it for granted that it is perfectly consistent to be unsure--that it is possible to live and not know. But I don't know whether everyone realizes that this is true. Our freedom to doubt was born of a struggle against authority in the early days of science. It was a very deep and strong struggle. Permit us to question--to doubt, that's all--not to be sure. And I think it is important that we do not forget the importance of this struggle and thus perhaps lose what we have gained. Here lies a responsibility to society.

We are all sad when we think of the wondrous potentialities human beings seem to have, as contrasted with their small accomplishments. Again and again people have thought that we could do much better. They of the past saw in the nightmare of their times a dream for the future. We, of their future, see that their dreams, in certain ways surpassed, have in many ways remained dreams. The hopes for the future today are, in good share, those of yesterday.

EDUCATION, FOR GOOD AND EVIL

Once some thought that the possibilities people had were not developed because most of those people were ignorant. With education universal, could all men be Voltaires? Bad can be taught at least as efficiently as good. Education is a strong force, but for either good or evil.

Communications between nations must promote understanding: so went another dream. But the machines of communication can be channeled or choked. What is communicated can be truth or lie. Communication is a strong force also, but for either good or bad.

The applied sciences should free men of material problems at least. Medicine controls diseases. And the record here seems all to the good. Yet there are men patiently working to create great plagues and poisons. They are to be used in warfare tomorrow.

Nearly everybody dislikes war. Our dream today is peace. In peace, man can develop best the enormous possibilities he seems to have. But maybe future men will drink out of boredom. Then perhaps drink will become the great problem which seems to keep man from getting all he thinks he should out of his abilities.

Clearly, peace is a great force, as is sobriety, as are material power, communication, education, honesty and the ideals of many dreamers.

We have more of these forces to control than did the ancients. And maybe we are doing a little better than most of them could do. But what we ought to be able to do seems gigantic compared with our confused accomplishments.

Why is this? Why can't we conquer ourselves?

Because we find that even great forces and abilities do not seem to carry with them clear instructions on how to use them. As an example, the great accumulation of understanding as to how the physical world behaves only convinces one that this behavior seems to have a kind of meaninglessness. The sciences do not directly teach good and bad.

Through all ages men have tried to fathom the meaning of life. They have realized that if some direction or meaning could be given to our actions, great human forces would be unleashed. So, very many answers must have been given to the question of the meaning of it all. But they have been of all different sorts, and the proponents of one answer have looked with horror at the actions of the believers in another. Horror, because from a disagreeing point of view all the great potentialities of the race were being channeled into a false and confining blind alley. In fact, it is from the history of the enormous monstrosities created by false belief that philosophers have realized the apparently infinite and wondrous capacities of human beings. The dream is to find the open channel.

What, then, is the meaning of it all? What can we say to dispel the mystery of existence?

If we take everything into account, not only what the ancients knew, but all of what we know today that they didn't know, then I think that we must frankly admit that we do not know.

But, in admitting this, we have probably found the open channel.

This is not a new idea; this is the idea of the age of reason. This is the philosophy that guided the men who made the democracy that we live under. The idea that no one really knew how to run a government led to the idea that we should arrange a system by which new ideas could be developed, tried out, tossed out, more new ideas brought in; a trial and error system. This method was a result of the fact that science was already showing itself to be a successful venture at the end of the 18th century. Even then it was clear to socially-minded people that the openness of the possibilities was an opportunity, and that doubt and discussion were essential to progress into the unknown. If we want to solve a problem that we have never solved before, we must leave the door to the unknown ajar.

OUR RESPONSIBILITY AS SCIENTISTS

We are at the very beginning of time for the human race. It is not unreasonable that we grapple with problems. There are tens of thousands of years in the future. Our responsibility is to . . . .

Senior Science

Enrichment Modules

THE LEBON PRIZE

TEACHING HINTS

FOR

THE LEBON PRIZE

1. This module should take about one hour.

2. Before the lesson, give the students the handout, THE LEBON PRIZE.

3. Give each group a particular research team title. Examples:

University of Saskatchewan	University of Regina
University of Manitoba	University of British Columbia
University of Toronto	McGill University

4. Use any suitable scenic jig-saw puzzle (a Saskatchewan prairie scene is good) for the pieces in each envelope. The puzzle is best broken up into six vertical strips.

5. The teacher (an extra helper would be very useful) should act as recorder and judges.

6. Allow about twenty-five minutes maximum for the puzzle section.

7. Stress the not more than twenty words for the hypothesis. Reject any of more than twenty words.

8. The journal is best done on the blackboard by the students.

9. Allow at least five minutes at the end of the lesson for the awards and summary.

10. Students should hand in work for evaluation.

THE LEBON PRIZE

Six research teams will be working towards the prestigious "Science and Society" Lebon Prize. In order to help your team it is suggested that you make yourself familiar with the following procedures before entering for your class:

1. Each research team will receive an envelope containing a ruler, and a portion of a puzzle.

2. The first stage for the Lebon Prize consists of a team effort in completing their section of the puzzle. Once it is completed, the team must report to the Project Recorder. Points awarded for the team puzzle section will be:

   5 points for first completed and recorded
   4 points for second .....
   3 points for third .....
   2 points for fourth .....
   1 point for fifth .....

3. Each team will formulate a hypothesis as to the "complete picture" of the research project. A written statement of not more than 20 words must be handed to the Recorder.

   The judges will award points for each hypothesis on the following basis: Good hypothesis 5 points; Fair hypothesis 3 points; Poor hypothesis 1 point.

4. Each team will prepare a written report for publication in the "JOURNAL." The report should describe their particular section of the puzzle in sufficient detail to enable the other research teams to get the "complete picture."

   Each team will give 1 point to the best report. The judges will award points on a 5, 3 or 1 scale, depending upon the quality of the reports.

5. Each team will sketch in the "complete picture." The picture will be given to the Recorder.

   The judges will award points for merit: Good 5 points; Fair 3 points; Poor 1 point.

6. Each member of the winning research team will receive the Lebon Prize.

STUDENT WORKSHEET

FOR

THE LEBON PRIZE

1. What prize do you think the Lebon Prize is simulating?

2. What research team was your group representing?

3. Name the members of your group.

4. Name the Lebon Prize winning group.

5. Suppose one of the research teams gave false information in their "JOURNAL" report. What would this have done to the end result of the Lebon Prize?

6. List in point form any improvements which you could suggest to improve the Lebon Prize module.

The Lebon Prize

RESEARCH TEAM HYPOTHESIS

The Lebon Prize

JOURNAL ARTICLE

The Lebon Prize "Complete Picture"

			38		

The Lebon Prize

SCORE SHEET

Team	Puzzle Completion	Hypothesis	Journal Article		"Complete Picture"
			Judges	Team	

McGILL UNIVERSITY

RESEARCH TEAM

UNIVERSITY OF MANITOBA

RESEARCH TEAM

UNIVERSITY OF B.C.

RESEARCH TEAM

UNIVERSITY OF TORONTO

RESEARCH TEAM

UNIVERSITY OF SASK.

RESEARCH 45 TEAM

UNIVERSITY OF REGINA

RESEARCH TEAM

Senior Science Enrichment Modules

The Lebon Prize

This is to certify that the holder of this certicate has been a member of a successful scientific research team.
Their research was of a basic character and involved team work, hypothesis making, journal reporting, and obtaining the "complete" picture for the problem at hand

This certificate is duly signed and authorized by:

Don Johnson
Allen Fedorak
Gene Sereshen

Senior Science

Enrichment Modules

DR. STUFFY

48

TEACHING HINTS

FOR

DR. STUFFY

1. This module should take approximately one hour.

2. Students should be assigned roles, each group responsible for a particular sector of society:

SECURITY	SCIENTIFIC COMMUNITY
Royal Canadian Mounted Police	National Research Council
Local Police	Saskatchewan Research Council
Army	Royal Society of Canada
Navy	Institute of Physicists
Air Force	Institute of Chemists
Law Society	Institute of Biologists

TRANSPORTATION	LABOUR
Air Canada	Canadian Union of Public Employees
Canadian Pacific	Canadian Labour Congress
Canadian National	Saskatchewan Union of Nurses
Associated Travel Agents	Canadian Union of Postal Workers
Manchester Liners	Union of Bank Workers
Allied Van Lines	National Farmers' Union

BUSINESS	GOVERNMENT
Eatons	Immigration
The Bay	Health and Welfare
International Business Machines	Justice
General Foods	Finance
Local Chamber of Commerce	Education
International Nickel	Local Government

3. The teacher (or better, a special guest) should play the role of Dr. Stuffy. This part, giving information to the committee about the invention, etc., should take about fifteen minutes. There is lots of leeway within the introduction for the teacher to extend, or diminish, the invention.

4. Each sector must prepare a brief for presentation to the whole committee.

5. Sector report to committee.

6. Final decision re: Dr. Stuffy. A committee vote could be taken.

7. Students should hand in work to be evaluated.

BRIEF RE: DR. STUFFY

Dr. I.M. Stuffy and a staff of two have been conducting research on energy matter transportation--in fact they have been using Einstein's familiar formula $E = mc^2$.

They recently have reported a breakthrough in matter transportation. It appears that they have constructed a facility which can transport matter (up to two hundred kilograms) to any place on the earth's surface and return it in tact. The entire transportation takes place at the speed of light ($C = 3 \times 10^8$ m/s).

Dr. Stuffy is now at the stage of development where he has applied for a patent for his invention.

It seems to the government that this invention has far-reaching implications. As such, we have invited Dr. Stuffy to meet with this Science Advisory Committee. At this time, we would like you to thoroughly analyze the situation and come up with some concrete proposals regarding Dr. Stuffy's work.

STUDENT WORKSHEET

ON

DR. STUFFY

1. State your role in the simulation.

2. Write down, in simple terms, your first reaction to the discovery of Dr. Stuffy.

3. Notes upon the discovery:

4. State the names and roles of the other members of your discussion group.

5. Group notes for presentation:

6. Class Decisions:

   (a) Dr. Stuffy's discovery is good/bad for Canadian society.

   (b) Recommendations:

SCIENTIFIC COMMUNITY

NATIONAL RESEARCH COUNCIL

54

55

SCIENTIFIC COMMUNITY

SASK. RESEARCH COUNCIL

SCIENTIFIC COMMUNITY

ROYAL SOCIETY OF CANADA

58

SCIENTIFIC COMMUNITY

INSTITUTE OF PHYSICISTS

SCIENTIFIC COMMUNITY

INSTITUTE OF CHEMISTS

SCIENTIFIC COMMUNITY

INSTITUTE OF BIOLOGISTS

SECURITY GROUP

64 ROYAL CAN. MOUNTED POLICE 65

SECURITY GROUP

LAW SOCIETY

50

66

SECURITY GROUP

67 AIR FORCE

51

SECURITY GROUP

NAVY

52

SECURITY GROUP

ARMY 69

53

SECUNITY GROUP

LOCAL POLICE

GOVERNMENT DEPARTMENTS

HEALTH AND WELFARE

GOVERNMENT DEPARTMENTS

JUSTICE

GOVERNMENT DEPARTMENTS

FINANCE

GOVERNMENT DEPARTMENTS

EDUCATION

58

GOVERNMENT DEPARTMENTS

LOCAL GOVERNMENT

GOVERNMENT DEPARTMENTS

IMMIGRATION

LABOR GROUP

SASK. UNION OF NURSES

LABOR GROUP

NATIONAL FARMERS UNION

62

LABOR GROUP

CAN. LABOR 81 CONGRESS

LABOR GROUP

CAN. UNION OF PUBLIC EMPLOYEES

LABOR GROUP

84

UNION OF BANK WORKERS

85

65

LABOR GROUP

CAN. UNION OF POSTAL WORKERS

BUSINESS COMMUNITY

NTERNATIONAL BUSINESS MACHINES

88

89

97

BUSINESS COMMUNITY

LOCAL CHAMBER OF COMMERCE

BUSINESS COMMUNITY

GENERAL FOODS

BUSINESS COMMUNITY

EATON'S

BUSINESS COMMUNITY

INTERNATIONAL NICKEL

BUSINESS COMMUNITY

THE BAY

72

TRANSPORTATION GROUPS

ALLIED VAN LINES

96

73

TRANSPORTATION GROUP

MANCHESTER LINERS

74

TRANSPORTATION GROUP

98 ASSOCIATION OF TRAVEL AGENTS 75

TRANSPORTATION GROUP

CANADIAN PACIFIC

76

TRANSPORTATION GROUP

CANADIAN NATIONAL

77

TRANSPORTATION GROUP

AIR CANADA

Senior Science

Enrichment Modules

NUCLEAR POWER

AN UNCLEAR STORY

TEACHING HINTS

FOR

NUCLEAR POWER

1. This module should take approximately one hour or more depending upon resources used.

2. Possible films that may introduce the topic:

   ENERGY: A CONVERSATION, a 30-minute film #531.6, SaskMedia

   WORLD WITHIN WORLD, a 50-minute film #539, SaskMedia

   LOVEJOY'S WAR AGAINST THE NUCS, a 50-minute film, Saskatoon Public Library

3. Have students read the newspaper article.

4. Have students do question 1 of the worksheet.

5. Have students read NUCLEAR POWER, Article #1.

6. Have students read NUCLEAR POWER, Article #2.

7. Participate in a debate.

8. The students should hand in work for evaluation.

STUDENT WORKSHEET

ON

NUCLEAR POWER - AN UNCLEAR STORY

1. Based on your personal feelings about nuclear power, choose one of the following alternatives:

   (a) Canada should develop nuclear power plants as energy sources, and deal with resulting problems.

   (b) Canada should ban nuclear power plants, and deal with resulting energy shortages.

2. Read the articles by Dr. Kim Krens (Pro) and Mr. Michael Bein (Con).

3. Summarize what you consider to be the main points of the articles which support your choice.

4. Participate in the debate.

5. Was your point of view changed by the debate? Why or why not?

Article #1 - NUCLEAR POWER

by

Kim Krenz*

*Mr. Krenz is a public relations officer with the Atomic Energy of Canada Ltd.

Article #1 - NUCLEAR POWER

The uranium atom does not, of course, have political affiliations. Some may wish it did! The uranium atom is simply there; and in Canada it is "there" in considerable abundance. This is fortunate, because the uranium atom presents us with one of our most important sources of energy.

So, why the "conservative" uranium atom? Well, first of all, compared to the enormous volumes of space and matter involved in other types of energy supply, the uranium fuel required to produce power for the city of Toronto from now to the end of the century could be stacked like cordwood to should height on your standard hockey rink.

Secondly, the use of uranium as fuel will let us conserve our precious reserves of oil and gas. The plain fact about oil and gas is that they are too valuable to burn in power stations. They are without doubt the most convenient fuels the world has ever known and we should be reserving them for the uses for which they are best suited, such as fuels for transportation and as the starting materials for plastics and fertilizer production.

Energy can be produced much more cleanly and with far less impact on the environment by producing it from the uranium atom. Now this will need amplification, especially since critics of the uranium route have said a lot of negative things about this alternative.

For example, the critics have complained that nuclear power plants using uranium emit large quantities of waste heat to the environment. What people don't seem to realize is that both coal and nuclear plants discharge large quantities of waste heat to the environment. Nuclear plants do reject somewhat more than coal-fired plants but fortunately in Canada we have such an abundance of cold water that this reject heat presents no problem. The effluent areas near both the Lakeview coal-fired plant and the Pickering nuclear plant have been extensively studied over a number of years and about the only significant observation was that the best place to catch fish in the area is in the effluents. Adverse effects could be created if one located a large power station on a small river, so we must locate our plants judiciously. We must also be sure that people aren't led to believe that the environmental hazards of a poorly-located plant in Florida are going to be duplicated in a well-located plant in Canada.

Perhaps the greatest disparity with respect to the environment occurs in the mining operation. No mining operation is impact-free and no one would claim that the uranium mining operation is a cleaner operation than the coal mining operation. Both have their problems and in both cases significant progress is being made to solve these problems. The difference is inherent in the quantity of material mined. One tonne of

uranium produces as much energy as 30,000 tonnes of coal, so even though the uranium concentration in ores is low, you still have to move at least 100 times as much material per unit of energy if you use coal. The impact of moving this vast quantity of material simply has to be greater, even if both operations are conducted with utmost care.

It must also be said that nuclear energy is safer than coal. This is a statement that most nuclear critics would dispute most violently. You may have heard or read about the disasters that could occur through the nuclear energy. But you've never read or heard much about anything that has happened. This is because very little has happened. The critics like to talk about events that have a possibility of happening perhaps once every 1,000,000 years, but they very conveniently overlook the probability. Consequently, people are given the impression of real danger when in fact the record shows that the industry is very safe, indeed. Let's just take a look at some of the myths that have been perpetuated and see if we can put them in the proper context:

1. The critics would like you to believe that the mining and refining of uranium, the fabrication of nuclear fuels, the transport of uranium fuels and the operation of nuclear power stations are all very hazardous operations. The record shows that all of these steps have led to a fatality rate of about 0.3 people per 1000 megawatts of electrical capacity per year. The comparable figure for coal-fired units is about three people per 1000 megawatts per year. This does not mean, of course, that coal-fired generation is an unacceptably hazardous operation. The accident rate is comparable to that of many industrial activities. However, the nuclear accident rate is considerably better. This shouldn't be surprising because the nuclear industry operates under much more stringent design codes and licensing practices than any other industry. Although the taxpayer ends up bearing the cost, nevertheless these are the codes that are adhered to.

2. A second thing the critics would like you to believe is that managing radioactive wastes is a particularly hazardous problem. Technically, it is probably one of the simpler problems we will have to deal with. Wastes will be buried in a geologic structure that has remained undisturbed for several hundred million years. Canada has thousands of square miles of such geologic structures and we will require perhaps one square mile to store the wastes we produce in the next 100 years. This is an easy technical problem; but a very difficult public relations problem. The difficulty is that the public has been led to believe that radioactive materials are some new and horrible poison, far worse than anything the world has ever seen before. In actual fact, ever since civilization began, the earth's crust has contained far more radioactive material than we will ever produce from nuclear power stations. Nature protects us from this hazard by enveloping this material in the rocks and soils of the earth's crust. This is

exactly what we propose to do with the radioactive wastes from nuclear power stations.

3. A third thing the critics would like you to believe is that any high school student could hijack a few kilograms of uranium fuel and contrive an atom bomb in his garage. This is ridiculous. When spent fuel is removed from a reactor, it consists of a mixture of unburned uranium, fission products and plutonium (the last amounting to about .2 per cent). At the very least, any would-be terrorist would have to hijack about a tonne of radioactive fuel, then separate the plutonium in a very sophisticated chemical separation plant before he even had his starting material. Then, he would have to have considerable technical knowledge to make his bomb. There are simpler ways to create terror, as we unfortunately too often see.

4. Fourthly, critics promulgate the theory that anyone living close to a nuclear power station risks danger from gaseous radioactive effluents. The fact is, the gaseous effluents from the Pickering station have been such that a man standing at the edge of the property 24 hours a day for a whole year would be subject to about as much exposure, in addition to natural background, as a man taking one return trip in a jet aircraft from Toronto to Vancouver. This is about five millirem (a unit of radiation) per year and natural background in North American varies from about 100 to 200 millirem per year, depending on where you live. We should certainly be cautious, but not hysterical. Going back to our comparison to nuclear and coal-fired stations, I think it's fair to say that we can minimize the hazards from the gaseous effluents from nuclear stations far more easily than we can those coal-fired stations. I think we understand the hazards better. Again, emphasizing that I am not implying that the hazards from coal-fired stations are unacceptable; only that those from the nuclear station are less.

Finally, it is already apparent that energy from uranium will be cheaper than coal. Let's look at actual cost figures published by Ontario Hydro in April 1975, comparing the cost of electricity from their uranium-fuelled Pickering station and their coal-fired Lambton station. The stations are the same size, 2,000-megawatt; they were built at the same time and this calculation was made assuming that they operated at the same capacity factor of 80 per cent. In fact they didn't; the Pickering station was used at a much higher capacity factor simply because it was producing electricity at a lower cost. The actual cost of energy from Pickering was 7.03 mills per kilowatt hour and energy from Lambton cost 13.26 mills per kilowatt hour. The Lambton cost would increase to 16.18 mills per kilowatt hour when new coal was purchased later in the year. This does not imply that anyone is going to start building a nuclear plant today to produce electricity for 7 mills per kilowatt hour or that this same comparison will necessarily hold true for plants built in other

parts of the country. All construction costs have shot up and a significant part of Ontario's coal cost is for transportation. Nevertheless, the cost comparison will indicate that you don't have to be very far from a coal field before nuclear power costs start looking pretty attractive. Alberta and British Columbia will probably continue to depend upon coal because they have it close at hand, but the time you get as far as the coal fields as Manitoba the pendulum has started to swing the other way.

Does the uranium atom justify the label "conservative"? Well, operation of the Pickering plant to the end of 1975 has produced the energy that would have come from 58 million barrels of oil. That's 58 million barrels we won't have to use.

Article #2 - NUCLEAR POWER

by

Michael Bein*

*A member of the Canadian Coalition for Nuclear Responsibility (CCNR) which was formed last summer in response to a surge of concern by individuals and groups across Canada. The Coalition is calling for complete public accountability on the nuclear energy question, along with full disclosure of all pertinent information. As a possible mechanism for realizing these objectives the Coalition is challenging the federal government to conduct a public enquiry into all aspects of nuclear power development in Canada "in order to acquaint the public with the hazards and benefits of nuclear power."

Article #2 - NUCLEAR POWER

Nuclear industry safety studies often yield absurd results when used to predict the probabilities of failures which actually have occurred in nuclear plants. A certain class of U.S. reactor accidents, for example, was predicted by perhaps the most exhaustive safety study ever done, to have a probability of 2.5 per billion billion (10^{18}) reactor years. Yet already 15 such accidents have occurred!

Although the likelihood of a major malfunction at a nuclear power plant seems to be anybody's guess, there is much less controversy about the extent of the damage that will occur if a reactor containment vessel does rupture, spreading a lethal cloud of radiation possibly for hundreds of miles across the countryside. Such an event, whether caused by accident or malice, can kill tens of thousands of human beings and cause billions of dollars worth of property damage. Small wonder then that insurance companies refuse to provide any sort of coverage for the Canadian nuclear industry.

AECL, meanwhile, expects to build over a hundred new reactors in this country. If the insurance companies won't trust that they are safe, then why should the public?

Fortunately, according to findings of the Science Council of Canada, there exists a clear alternative to rapid nuclear expansion. It is evident from their report on energy conservation, that simply improving the efficiency of our present energy use by two per cent can save us more energy between now and the year 2000 than nuclear sources can produce in that time period, and without any major shift in lifestyles. More recent SCC releases indicate that conservation "produces" energy at one tenth the dollar cost of large scale development schemes such as nuclear. Conclusions such as these shed considerable light on the true nature of the so-called "energy crisis"--and considerable doubt on the arguments of the nuclear proponents that their way is the only way to ensure a comfortable standard of living.

With this safe, practical alternative to nuclear power in mind, let us take a closer look at the 15 other points outlined in the preceding article.

1. Uranium is abundant in Canada: If this is true, then why are many scientists and senior government officials predicting a "uranium crisis" in 10 to 15 years?

2. Uranium fuel is advantageous because of its small volume: That is about the only reason. Uranium is radioactive. Minute quantities can cause cancer or genetic damage. Nature takes thousands of years to render uranium harmless, a task which men have not yet learned to do.

3. Uranium enables us to conserve oil and gas: This is perhaps the biggest myth of the nuclear industry, as well as the theme song of AECL's preceding article. Although it has a nice ring to it in theor, in practice the staggering amounts of fossil fuel energy necessary to construct large nuclear power stations from scratch will more than compensate for all the electricity they will produce until far into the next century. For this reason, nuclear power can do nothing to relieve our present "energy crisis."

4. Waste heat from nuclear power plants can be, and is, handled effectively by judicious plant location: Without going into the record of the Point Lebreau, N.B. siting of a nuclear power plant, which has left a lot of people very dissatisfied on this and other points, let us consider the global (as distinct from local) effects of waste heat, about which AECL has said nothing. According to the basic laws of physics (The Laws of Thermodynamics) reactor waste heat constitutes an indestructible form of pollution. Although it can be routed locally (via a river or lake, or the air), it is technically impossible to keep this thermal pollution from ending up somewhere in the global ecosystem. Scientists have been expressing a growing concern for years that all the waste heat from large scale nuclear production will affect the earth's climate, perhaps severely and irreversibly, though the formation of "heat islands" such as those that currently surround major cities, if not through the outright melting of the polar ice caps of the earth. Such thermal considerations would incriminate any type of rapid large scale energy growth, but particularly nuclear, which produces over 50 per cent more waste heat than conventional systems in generating an equivalent usable power output.

5. Uranium mining is much less hazardous to the environment than coal mining: AECL again pulls that lone ace from its sleeve: small volumes of material. Yet Elliot Lake, Quirke Lake, and the Serpent River system have suffered permanent radioactive contamination as a result of uranium mining. And, of course, there is Port Hope.

6. Very little has happened in the way of nuclear accidents: Often has a malfunction which started in a nuclear plant managed to grow to dimensions large enough to break through the veil of secrecy that generally surrounds the accident records of the nuclear industry. Does AECL still turn a blind eye to the NRX (reactor) accident at Chalk River, Ont. in 1952; the catastrophic Windscale accident in Northern England in 1957; the Fermi accident near Detroit in 1966; the Lucens accident in Switzerland in 1969; and the Brown's Ferry accident in Alabama in 1975? And these are only the big ones.

7. Fatality rates are low in the nuclear industry: This industry is still in its infancy. Must we see the effects when these hazardous procedures become routine and not just practiced in a few places?

Must we wait until there is shortage of qualified personnel to judge this issue fairly? Already 450 Canadian uranium miners are dying from lung cancer and silicosis. Sixty have already died.

8. Design codes and licensing practices are more stringent than in any other industry: Then they are either not being enforced or they are not stringent enough, as the tragedy of the miners and the case of Port Hope illustrate. Both of these calamitous situations could have been prevented through proper regulation.

9. Radioactive wastes can easily be buried in geologic structures that have remained undisturbed for several hundred million years: This is not true. There is not a responsible geologist in the world who can guarantee the integrity of <u>any</u> geological structure for the hundreds of thousands of years necessary to safeguard the environment from the enormous amount of toxic, radioactive garbage that is produced by nuclear reactors. The only geological disposal scheme tried anywhere thus far, the Salt Vault Project in Kansas, was abandoned as far too hazardous to use, after 15 years of study costing more than one hundred million dollars.

10. Nuclear materials have always abounded in the earth's crust: One can only suppose that AECL has never heard of plutonium, a deadly poisonous, radioactive, fissionable (i.e., a nuclear explosive) element that is never found in nature, but is always found in the wastes of CANDU reactors. Furthermore, there is a difference between leaving dangerous substances sparsely distributed in the earth's crust where they can do no harm, and dredging them up to the surface where they can permanently contaminate the ecosystem.

11. It is impossible for a high school kid to make an atom bomb: A high school kid in Miami has already presented sufficiently accurate blueprints of an atom bomb to police that he was apprehended only after a million dollar extortion payment had been made. All he really lacked was the explosive material (plutonium or "enriched" uranium) and it is getting easier to find in Canada every day. High grade plutonium is produced at a million dollar "experimental" plant at Chalk River. And let's not forget terrorist groups and hostile governments, as well as high school students.

12. The exposure of people at the edge of the Pickering site is only 5 millirem per year: It is much higher for workers inside the plant, or if and when the plant fails to function properly. Natural radiation cannot get lodged in people's lungs like the emissions from Pickering. And doctors are not sure that <u>any</u> level of radiation is safe!

13. Minimizing effluent hazards is easier with nuclear than with coal: Again the AECL ace: small quantities of materials. Again the materials are radioactive; only this time gaseous and capable of being absorbed from the air by vegetation and becoming caught up in food chains.

14. Nuclear energy is cheaper per kilowatt hour than coal: Even if this were true, in view of all the dangers one would still be inclined to wonder "so what?" But as John Foster, Chairman of AECL admitted last November before a House of Commons committee, rates at the Gentilly, Que., nuclear power station had already climbed to above 20 mills per kilowatt hour. This is well above the Lambton (coal) figure and about triple the 7 mills given for Pickering in the AECL article. For a variety of reasons, nuclear power costs in general are skyrocketing out of all proportion to costs in other industries.

15. By the end of 1975, Pickering had saved 58 million barrels of oil: This is again typical of the nuclear industry's fault energy accounting practices. Although we don't have figures on how much oil was used to build and operate the Pickering plant, one thing is clear: no business would look at its earnings and decide it was well off without taking into account its expenses!

This article by no means presents the whole case against nuclear power. There are a number of considerations, particularly social issues, that have only been touched on here or not mentioned at all. These would include, briefly: militarization of our transport and other systems; the strict regulation of large sectors of our work force (whose responsibilities would be comparable to those of present day air traffic controllers, and who would be just as fallible); the creation of a small but powerful nuclear scientific "priesthood"; increased unemployment as a result of energy displacing labour; failure to be able to provide technologies adaptable to the needs of our less developed neighbours; and increased urbanization as the result of extraordinarily centralized nuclear technology.

Perhaps even more disturbing than any of these is nuclear energy's tendency to become addictive. To go too far down the nuclear road now is to develop such a massive energy deficit that the only way to recover may be with more power plants, more hazards, more controls on society, more thermal pollution, and on and on.

As things stand now our society, through the practice of sane conservation measures, is in a position to use the next 25 years, while fossil fuels are still relatively abundant, to develop safe alternatives to nuclear power. None of these has ever been blessed with even a fraction of the incentive subsidies that nuclear development has. If we continue our current trend, down the path of nuclear development, in 25 years most

of the oil will be gone and we may find ourselves locked into a nuclear future whether intended or not.

Finally, and perhaps most significantly, a commitment to nuclear energy development is a commitment to inflict upon the next 8,000 generations of Canadians the unwholesome task of guarding our toxic, radioactive garbage against leakage and theft, earthquake and sabotage, accident and malice. Who among us, in good conscience, can pass on a heritage like that?

PUBLIC APATHY ON NUCLEAR ISSUE

by

Richard Gwyn (1978)

PUBLIC APATHY ON NUCLEAR ISSUE

The question put to a recent seminar at the Harvand University Law School was not so much a tough one as an agonizing one. Suppose that terrorists stole a nuclear reactor fuel rod composed of readily fissionable Plutonium-239. To make a bomb you need just 15 pounds of the stuff. To what extent should civil liberties be suspended? Should the police for instance, be allowed to torture suspects?

In Sweden, public hostility to nuclear power (and to high taxes) recently defeated the 44-year-old Social Democrat government. In California, the legislature has banned all nuclear power development until convinced by Washington that reactor wastes can be safely disposed of.

In Canada, we mostly yawn.

While we've been yawning, the government, federal and Ontario provincial in con-ert, has put us on the nuclear treadmill. We're there, without knowing whether we need to be, whether we ought to be, how fast the treadmill will make us run, and in what direction it will take us.

This fall, the Ontario royal commission on electric power planning will publish the first, full-scale Canadian study of nuclear energy. It amounts to a wingshot at a target that already is almost out of sight. Even now, 4,500 megawatts of electricity are being generated by nuclear reactors. By the year 2000, plans call for a 15-fold increase, to 75,000 megawatts. In Ontario, two-thirds of the electricity of 2,000 will be generated by nuclear reactors. The investment, in capital, in manpower and in corporate prestige (Ontario Hydro), almost is irreversible.

Public apathy, to a point, is understandable. The subject is intimidatingly technical. A layman's small stock of remembered school science soon falters in the face of the jargon, "rems" (Roentgen equivalent man) and "rads" (Radiation Absorbed Dose), used in just one area--to measure the radioactive risks to humans.

A more profound reason, which may explain the contrast between public attitudes here and elsewhere, has been summarized perfectly by the pro-industry Canadian Nuclear Association. The CANDU reactor system, the association points out, "is Canadian . . . the most significant and successful activity in the field of high technology ever undertaken and brought to commercial fruition in Canada."

True. So the sales of CANDU reactors to Argentina and South Korea were a bit of an embarrassment. So who, for a second, doesn't believe that the Americans, the French, the British, the Germans, don't dish out even larger bribes to secure sales?

Pride in the accomplishment of Canadian scientists and engineers, however, is beside the point. The question is whether, no matter how well they are doing it, they should be doing it at all.

The real point is that each step taken on the nuclear treadmill leads inevitably and inexorably, to the next. Once on it, we cannot get it off, pleading later, "I didn't realize this would happen."

A garrison state is one thing that may happen. Today, the reactors' wastes, or spent fuel rods, which remain radioactive for up to one-quarter of a million years, are stored in temporary "swimming pools" at the reactor sites. As more reactors are built, more wastes pile up--an estimated 2,500 train shipments a year by the end of the century. The industry now admits is should have found a permanent solution before beginning large-scale reactor construction.

The problem of the solution to waste disposal is that it in turn creates entirely new problems. One solution, for instance, is reprocessing, which reduces the volume of the wastes by extracting out plutonium to be re-used as fuel. Those plutonium rods, though, are a natural target for countries or for terrorists seeking the bomb. This is why U.S. President Carter has banned reprocessing, though it continues to be done in Europe.

An alternative solution is "irretrievable" disposal in deep shafts in the igneous rock of Northern Ontario. The technique is unproven. Even if it does, these sites will have to be placed under military guard, by ourselves, by our children, by their children, and by their's on into the indefinite future.

Military guards will have to be placed as well--an issue the industry has been silent about--at decommissioned nuclear reactors once they reach the end of their 30-year-life span. By the year 2000, we'll have 100 reactors. Soon after that, we'll have 100 radioactive hulks.

These are the so-called "back-end" problems of nuclear power. The "front-end" problems are worse. The tailings of uranium mines are more radioactive than reactor fuel wastes. Not a fish is left in the 55-mile stretch of the Serpent River before Elliot Lake. The more nuclear power is generated, the more uranium will have to be mined.

These are signs of change in public attitudes. Recently, the Canadian Medical Association, a soberly conservative body, approved a resolution calling for a halt to nuclear power development until a medically-safe system of waste disposal has been established. In Thunder Bay, 17,000 citizens have signed a petition demanding a full-scale inquiry before a disposal site is picked in Northern Ontario. Ottawa's response has been to sign a contract with Ontario Hydro to develop a waste disposal program to pick the first site by 1983.

The treadmill is turning. How many more, unexamined, undebated, steps do we have to take before some future prime minister goes on television to tell the public, "Reports . . . still being verified, indicate that a plutonium fuel rod may be missing. Therefore, the War Measures Act . . .".

Senior Science

Enrichment Modules

HERZBERG LECTURE

ON THE

BOUNDARIES OF KNOWLEDGE

TEACHING HINTS

FOR

HERZBERG LECTURE

1. This module should take approximately one hour.

2. Have students read the lecture or, if possible, listen to the tape recording of the lecture. The students should complete the note sheet while doing this.

3. Allow time for the students to discuss the main ideas on the student worksheet.

4. Reference for the lecture: TRANSACTIONS OF THE ROYAL SOCIETY OF CANADA, 1974.

5. Other resources which could be used: DIMENSIONS OF CHANGE, SUNBURST COMMUNICATIONS.

6. The students should hand work in for evaluation.

LECTURE NOTES

ON

HERZBERG LECTURE

Gerhart Herzberg is the Director of Pure Physics at the National Research Council of Canada. In 1971, he was awarded the Nobel Prize in Chemistry for his research in spectroscopy--connected with identifying elements existing in outer space.

Listen carefully to the tape (or read the essay) in which Herzberg is talking about the Boundaries of Knowledge. Make some notes as you listen/read under the headings given below:

1. Science Education

2. Examples of Boundaries of Knowledge:

   (1) The velocity of light (c) -

(2) Energy and Mass are equivalent ($E = mc^2$) -

(3) Cosmology -

(4) Atomic Theory -

(5) Heisenberg's Uncertainty Principle -

(6) The Copenhagen School -

(7) Intelligence and Memory -

(8) Practical considerations -

STUDENT WORKSHEET

ON

HERZBERG LECTURE

1. How long ago did Herzberg suggest that the last new physical law was established? What was it?

2. What is the boundary limit for communication?

3. Heisenberg's "Uncertainty Principle," what has it to do with? How is it a limit?

4. Discuss the boundary caused by intelligence.

5. What is the practical boundary?

6. Herzberg constantly stresses "knowledge for . . . ". Complete his quotation.

HERZBERG LECTURE ON THE BOUNDARIES OF KNOWLEDGE

The theme of this symposium is a philosophical one: the frontiers and limitation of knowledge. From a philosophical point of view, physicists (and most other scientists) are naive realists; they believe that the electrons and protons, the atoms and molecules they talk about, the planets, the stars really do exist and are not just figments of our imagination. The advent of the atomic bomb in 1945 demonstrated to the world that there is surely some reality in the results of research in the physical sciences.

The question to which the speakers in this symposium were asked to address themselves (as I understand it) was to what extent science can continue to search deeper and deeper for the nature of the world around us: are there limitations to our knowledge, boundaries beyond which we shall be unable to go?

The history of science and technology is full of developments in which boundaries previously believed to exist have been broken. These developments are usually of the type that a basic discovery is used for a practical invention or that an advance in technology makes possible the study of basic problems previously thought to be insoluble. I need only to remind you of the electrical transmission of power and of the invention of the telegraph, both made possible by Faraday's discovery of electromagnetic induction, or of all the medical progress made possible by Rontgen's discovery of x-rays, or of all the scientific discoveries based on the technological achievement of space flight.

In several instances, writers of science fiction like Jules Verne and his successors have predicted the advances of technology. Some of the advances envisioned by science fiction writers, however, are impossible because of certain basic laws of physics, for example, all perpetual motion machines contradict either the first or the second law of thermodynamics and all the "time machines" run counter to the unidirectional nature of time.

The present frontiers of knowledge in the physical sciences are largely determined by the extent to which the army of scientists has been able to advance, given the scientists' own intellectual power and interest, as well as the support by society. But to some extent these frontiers are or will be determined by the closeness to the boundaries that are inherent in the subject and that depends on the laws governing the physical universe. Here it is important to realize, as has been emphasized by John Wheeler, that for the last forty-five years, in spite of all the new developments in science, no new physical laws have been discovered that go beyond electromagnetism, relativity theory, and quantum theory. Can we believe that we are already in possession of all the basic laws?

Let us now turn to a discussion of a few examples of boundaries of knowledge which at least at present appear to be basic and are not likely to be removed in the future.

One of the most important consequences of the basic postulates of relativity theory is the statement that there can be no velocity greater than the velocity of light (c). This result (to which no exceptions have ever been found) presents a very fundamental boundary of knowledge. It limits the size of the observable universe since from a certain distance on we cannot observe astronomical objects because of the expansion of the universe and the increase of velocity of recession with distance; they would be receding with a velocity greater than that of light. It also follows that communications with other civilizations in other solar systems are severely limited because of the time involved in sending messages.

Another important consequence of relativity theory is that energy and mass are equivalent, and this result suggested that light quanta (photons) would have mass ($h\nu/c^2$) and would therefore be deflected in their paths by heavy masses (stars). Indeed the observation of this effect during the 1919 solar eclipse was the most important step in the general acceptance of relativity theory. An extreme consequence of this result is exhibited by the so-called black holes (first discussed in 1939 by J.R. Oppenheimer and H. Snyder). These are objects of such high density (formed by the gravitational collapse of stars) that light cannot leave them and any light or other particles that come near them will be swallowed up and can never escape. Any space traveller who encounters a black hole will not be able to send signals back to us to tell us of his experience. It is a clear-cut case of a boundary of knowledge which we cannot transgress. Of course one may ask the question: can one really extrapolate the results of relativity theory to the range of densities in which black holes are formed? There is always a singularity inside a black hole, that is, a point of infinite density. Such singularities can hardly be part of the real, physical world. Whenever they occur in a theoretical description of physical phenomena we know that a basic point must have been missed. It has been suggested by Wheeler and Thorne that the missing point may be the quantization of gravity. But whether this is so we cannot know until, as Wheeler expresses it, "the fiery marriage of general relativity with quantum physics has been consummated."

Still another boundary of knowledge resulting from relativity theory arises in cosmology. Most (but not all) cosmologists have accepted the idea, first proposed independently by Friedman and Lemaître and later extended and refined by Gamow and his collaborators, that our universe started with an original explosion, the so-called "big bang." Some ten years ago there suddenly emerged (so we are told) at a certain point in space the original explosion which eventually ended up in the formation of all galaxies (and solar systems) and in particular gave rise to the

observed expansion of the universe. The universal 3° K radiation recently observed as coming from all directions is considered to be evidence for the original explosion; it is the cooled down radiation field which at the start had a temperature of 10 degrees and was predicted by Gamow to have now a temperature of 10° K (a surprising agreement with observation).

The big bang model of the origin of the universe comes sufficiently close to the biblical description that it was actually adopted by Pope Pius XIII in an address to the members of the Pontifical Academy of Sciences in Rome in 1951. It is difficult for an outsider to see how the law of conservation of energy was maintained during the big bang. Apparently it is assumed to be an act of sheer creation. Indeed, at a lecture on the subject in Ottawa Gamow replied to a questioner who asked what preceded the big bang: "Hell was invented for those people who ask such questions." Gamow and his fellow cosmologists certainly appear to believe in a fundamental boundary of knowledge at this point. This boundary is connected with another singularity, the converse of that inside a black hole.

From a philosophical point of view the alternative cosmology of H. Bondi and T. Gold and of F. Hoyle appears to me more attractive. In it a stationary universe is assumed without a beginning. In order to account for the observed expansion these authors assume that H atoms (protons and electrons) are continuously being created in space at an extremely slow rate. It is sometimes argued that such speculations are useless since it would appear that we can never verify them. On the other hand more and more evidence is being accumulated that has a bearing on the problem and may be used to decide between competing theories. The observation of the 3° K radiation is a case in point. Even though the final word has not been spoken on its interpretation it is likely that it will play a decisive role in the formulation of our ideas about the origin of the universe.

Not very long ago it appeared that it would be impossible for man ever to know whether there is life on other worlds or to reach even the nearest celestial body, the moon, to find out. As recently as 1941 a distinguished member of this Society (the late J.W. Campbell of the University of Alberta) published a paper in the Philosophical Magazine in which he showed that the fuel required to take a man to the moon and back would have to have a mass 2 x 10 times that of the spaceship and that therefore a visit to the moon was not feasible. Since then we have all witnessed the visits of several teams of astronauts to the moon (the mass ratio was only 550), and of course they did not find any form of life on the moon. It will not be long before we know whether life exists on Mars.

Since the invention of the maser and laser it seems even feasible to make contact with advanced civilizations in other solar systems.

Several unsuccessful attempts have already been made and last year an international meeting specially devoted to this problem took place in the Soviet Union.

These remarks illustrate that there are boundaries which may at one time be considered unsurmountable but which become surmountable by unexpected advances in science and technology.

When atomic theory was first developed, few people thought that individual atoms or molecules would ever be detectable. Indeed their direct detection appeared to be beyond the boundaries of knowledge; only their collective action could be seen and measured. This is another boundary that no longer exists. First Rutherford and others showed that α particles as detected in counters represent individual helium nuclei. Later C.T.R. Wilson was able to detect tracks of individual α particles and soon after of electrons, protons, and other particles hav kinetic energy. More recently, by using electron microscopes and especially ion microscopes it has been possible to obtain photographs showing the arrangement of atoms or molecules on solid surfaces. But a new boundary soon became apparent. It was first formulated by Heisenberg in his famous uncertainty principle. This principle is of fundamental importance in any discussion of the boundaries of knowledge.

The resolving power of an optical microscope (and similar considerations apply to electron--and ion--microscopes) depends on the wave length of the light used: the shorter the wave length the greater the resolving power. In principle, by using γ-rays, that is, electromagnetic waves of exceedingly short wave length, we can increase the resolving power, that is, the accuracy with which we can determine the positions of a (sub)-atomic particle to any desired level. However, at the same time, since, because of the quantum nature of electromagnetic waves, each light quantum has a momentum hv/c, we are increasing the impulse acting on the particle we are observing, which gives it a certain momentum (that is, a certain velocity), and this momentum cannot be fully predicted: the uncertainty in this momentum is inversely proportional to the uncertainty of the position of the observed particle and the proportionality factor is Planck's constant:

$$\Delta p = m\Delta v \approx h/\Delta q \quad \text{or} \quad \Delta p \cdot \Delta q \approx h \ .$$

Another way of describing this uncertainty relation is by considering the diffraction of a beam of electrons (or other particles of light) at a slit. This diffraction results in a diffraction pattern on a plate at the right to the beam. This pattern, indicated by the blackening curve at the right in Figure 1, is, of course, produced by a large number of particles. If, however, we want to consider the motion of a single electron, then there is no way for us to decide into which maximum of

of the diffraction pattern the particle goes. All we can tell is the probability, which is indicated by the curve shown. The narrower the slit the wider is the diffraction pattern, therefore the more uncertain the subsequent motion of the particle at right angles to the original beam direction. That is, by establishing the position of the particle more and more accurately by narrowing the slit we make its velocity at right angles to the beam more and more indeterminate.

According to present thinking about quantum theory, our inability to predict the future motion of a particle is quite basic. It means that there is an intrinsic breakdown of the law of causality at the microscopic stage. Before the advent of quantum theory it was possible to say that if one only knew the positions and velocities of all particles in the universe at a given time with sufficient accuracy one could, in principle, predict the motions of these particles for all future times, that is, everything was determinate. According to quantum theory it no longer is.

One might argue, and it has been argued, that perhaps there are some unknown or hidden parameters which determine the point in the diffraction pattern to which a given single electron will move. But we cannot measure or observe these parameters (at least at present). The contention of the proponents of quantum mechanics, and in particular the Copenhagen school of quantum mechanics, is that if such hidden parameters existed they would lead to contradictions with the results of quantum mechanics and, as is well known, up to now all experimental data and observations are in accord with quantum mechanics. On the other hand, there are a few physicists who maintain that such hidden parameters are possible and that eventually a completely deterministic picture will result again. One of these was Einstein himself. Another is Louis de Broglie, the originator of the idea of matter waves. None of the proponents of hidden parameters have been able to convince the great majority of theoretical physicists, who maintain that there is no way out of the Copenhagen interpretation of quantum theory. We must therefore be prepared to accept that there may be a very basic boundary to knowledge.

Apart from the boundaries of knowledge that are intrinsic to the nature of our physical universe we should also consider those boundaries that are introduced by the human mind.

The distribution of intelligence amongst the human population is perhaps a curve of the type that I have sketched in Figure 2, similar to a Maxwell-Boltzmann distribution curve. It has a long tail at the right, which corresponds to the rare individuals with exceptional intelligence. It is these individuals who make the major contributions to knowledge. Men like Einstein, Newton, and others occur perhaps once in a century. They are distinguished by their enormous power of comprehension of the interrelation of facts which, to normal individuals, seem unconnected. If we did not have men like them the progress of science and the arts would be very slow indeed.

With the increase in population and in affluence, the number of people engaged in intellectual pursuits has increased tremendously and has led to the phenomena of knowledge explosion and publication explosion. Most of us can keep track only of an extremely limited field of knowledge. It is only a very few, far out on the tail of the intelligence curve, who are able to retain in their minds a large number of different aspects of knowledge, and it is therefore they who are preconditioned to make the great advances in knowledge, provided that they are sufficiently motivated to do so. With regard to the last qualification, it is perhaps interesting to recall that even a man like Isaac Newton had great inhibitions in publishing the results he had obtained.

What we must do if the advance of knowledge is our aim is to encourage the exceptional individuals who are endowed with unusual intellectual ability. Another obvious thing we should do is to support research in brain processes which might eventually lead to an improvement in intellectual capacity and particularly in memory, so that our minds can keep up with the ever-increasing mass of factual and theoretical concepts that the development of knowledge produces.

The limitations to the advance of knowledge that are introduced by the limited extent of our memory (and I realize that there are many other reasons) are illustrated by the sharp schism between literary intellectuals on the one hand and natural scientists on the other, so eloquently described by C.P. Snow in his little book, The Two Cultures and the Scientific Revolution. Of course, this schism really goes much further, as we recognized by C.P. Snow; even among scientists of one discipline there is considerable lack of understanding of the work in other disciplines. While much of this schism is caused by the limitations of the average intellect, the division is further fostered to a considerable degree by our educational system, which in my opinion gives far too much choice to students of our high schools. I recently came across a statement by Arnold Toynbee which illustrates this point. He said: "Looking back, I now regret that, at the age of sixteen, at school, I was allowed to choose between starting on calculus and giving up mathematics altogether in order to spend the whole of my working time on reading more widely in the Greek and Latin classics. I ought not to have been given this choice at that age. I chose wrong, and consequently the field of mathematics, and of the branches of science founded on mathematics, has been closed to me."

Finally I should like to discuss briefly the boundaries of knowledge that are due to practical considerations. The last ten years have seen an almost endless discussion of the problem of support and control of basic science. Because of the lack of understanding of the principal aims of science by our politicians, we try to impress them by the fact that basic science almost invariably leads to applications that are useful for the economy of the country and we omit to emphasize to them the need for basic research as a cultural activity of the same type as literature, art, and music. Even though the funds required for basic research are small, very small, compared to those required for the application of science in

industry, our politicians still have a tendency to limit the funds and to make them available only to those who can tie basic research to specific practical applications.

In the West we deplore the lack of freedom of writers, artists, and musicians in the countries on the other side of the Iron Curtain, and yet we don't seem to appreciate that the same kind of freedom and we give to our writers, artists, and composers in the West we must also give to scientists. It is they and they alone who can appreciate what is significant and worth doing in science. We saw examples of the influence of political dogma on a whole generation of geneticists in the Soviet Union when Lysenko reigned there. Or, quite recently, we have seen the names of prominent scientists erased from the literature simply because they expressed a wish to emigrate from the Soviet Union to Israel. All these occurrences remind us that freedom is as important for science as it is for literature, art, and music. In the struggle for social equality the necessity to maintain excellence in intellectual matters has often been ignored. Indeed, in a strictly egalitarian society excellence presents an awkward and embarrassing problem.

Suppose for a moment that the great geniuses of the past, Shakespeare, Goethe, Leonardo da Vinci, Rembrandt, Mozart, Beethoven, Schubert, Newton, Einstein, etc., had not lived or had been suppressed by an egalitarian movement. Would that not have taken away the major justification for the existence of mankind? Are not the supreme moments of the human race those in which a man of genius creates a work of art of eternal beauty or recognizes a law of nature or of thought that contributes in a significant way to our understanding of the universe we live in?

Of course, creative men of genius cannot live on their own. For one thing the human race must survive so that these men of genius can arise, and many able men and women are needed to ensure survival--physicians, politicians, engineers, etc. But let no one tell us that survival and improvement in the standard of living is to be the principal aim of society. Rather, let us develop a cultural climate which believes that human excellence is a good thing in itself, a climate in which all members of society can rejoice and delight in the things that the small number of exceptional members is able to do, without asking what use they have for survival. We must come to the point where even the average citizen considers the works of art, literature, and basic science as not merely the icing on the cake but as the essence of human existence. Without that, to quote C.P. Snow, "some of the major hopes, the major glories of the human race will rapidly disappear."

From the point of view that I have presented, the striving for excellence in order to increase our cultural heritage and to extend the frontiers of knowledge is the most important aim of mankind. There may be more urgent things to be done in connection with our survival. But we must not let these necessities detract us entirely from our devotion to the striving for knowledge for its own sake, to the aim of understanding man and his world.

Senior Science

Enrichment Modules

LIFEBOAT ETHICS

TEACHING HINTS

FOR

LIFEBOAT ETHICS

1. This module should take approximately one hour.

2. Briefly describe the situation to the class.

3. Have each individual student select the six survivors.

4. Break into groups of ten. Smaller or larger groups may be used. It is important to have a mix of males and females.

5. Assign a role to each member of the group, usually picking a number out of a hat is sufficient.

6. Have each student prepare a defence of why he should survive.

7. Let the groups work out their own survivor using group discussion.

8. Have groups report to the class, either verbal or on blackboard.

9. Have students read the articles.

10. Students should hand in work for evaluation.

BRIEF

ON

LIFEBOAT ETHICS

SITUATION

Biological warfare has killed all human beings except ten who escaped by sailing out onto the ocean for forty days and forty nights. After this time period, their supplies were depleted so that only six could return to land. The danger on land will have dissipated by the time these six reach land.

ROLES

1. Twenty-five year old pregnant woman who is a stenographer.
2. Forty year old parish minister.
3. Seventy year old M.D. who retired ten years ago.
4. Twenty year old engineering student who had completed three years of a four year program.
5. Thirty year old policeman with the only gun on board.
6. Eleven year old child.
7. Fifty year old farmer.
8. Sixty year old wilderness survival authority.
9. Forty year old crippled sailor. The only survivor with sailing experience.
10. Thirty year old psychologist who is an expert on group dynamics.
11. Forty year old university physics professor.
12. Thirty-nine year old manual laborer.

STUDENT WORKSHEET

ON

LIFEBOAT ETHICS

1. List the members of your lifeboat (include whether male or female).

2. Before any discussion, tentatively list who you think should survive from your lifeboat.

3. State your role, and include your personal defence for survival.

4. Notes upon other members of lifeboat.

5. Group decisions for elimination.

6. Final lifeboat occupants. How does it compare with your original selection? Can you explain for any differences?

7. In what way does your study of science help you in the Lifeboat Ethics simulation?

8. What do you think of Hardin's article?

LIFEBOAT ETHICS

THE CASE AGAINST HELPING THE POOR

by

Garrett Hardin

THE CASE AGAINST HELPING THE POOR

Environmentalists use the metaphor of the earth as a "spaceship" in trying to persuade countries, industries and people to stop wasting and polluting our natural resources. Since we all share life on this planet, they argue, no single person or institution has the right to destroy, waste, or use more than a fair share of its resources.

But does everyone on earth have an equal right to an equal share of its resources? The spaceship metaphor can be dangerous when used by misguided idealists to justify suicidal policies for sharing our resources through uncontrolled immigration and foreign aid. In their enthusiastic but unrealistic generosity, they confuse the ethics of a spaceship with those of a lifeboat.

A true spaceship would have to be under the control of a captain, since no ship could possibly survive if its course were determined by committee. Spaceship Earth certainly has no captain; the United Nations is merely a toothless tiger, with little power to enforce any policy upon its bickering members.

If we divide the world crudely into rich nations and poor nations, two thirds of them are desperately poor, and only one third comparatively rich, with the United States the wealthiest of all. Metaphorically each rich nation can be seen as a lifeboat full of comparatively rich people. In the ocean outside each lifeboat swim the poor of the world, who would like to get in, or at least to share some of the wealth. What should the lifeboat passengers do?

First, we must recognize the limited capacity of any lifeboat. For example, a nation's land has a limited capacity to support a population and as the current energy crisis has shown us, in some ways we have already exceeded the carrying capacity of our land.

Adrift in a Moral Sea

So here we sit, say 50 people in our lifeboat. To be generous, let us assume it has room for 10 more, making a total capacity of 60. Suppose the 50 of us in the lifeboat see 100 others swimming in the water outside, begging for admission to our boat or for handouts. We have several options: we may be tempted to try to live by the Christian ideal of being "our brother's keeper," or by the Marxist ideal of "to each according to his needs." Since the needs of all in the water are the same, and since they can all be seen as "our brothers," we could take them all into our boat, making a total of 150 in a boat designed for 60. The boat swamps, everyone drowns. Complete justice, complete catastrophe.

Since the boat has an unused excess capacity of 10 more passengers, we could admit just 10 more to it. But which 10 do we let in? How do we choose? Do we pick the best 10, the neediest 10, "first come, first served"? And what do we say to the 90 we exclude? If we do let an extra 10 into our lifeboat, we will have lost our "safety factor," an engineering principle, of critical importance. For example, if we don't leave room for excess capacity as a safety factor in our country's agriculture, a new plant disease or a bad change in the weather could have disastrous consequences.

Suppose we decide to preserve our small safety factor and admit no more to the lifeboat. Our survival is then possible, although we shall have to be constantly on guard against boarding parties.

While this last solution clearly offers the only means of our survival, it is morally abhorrent to many people. Some say they feel guilty about their good luck. My reply is simple: "Get out and yield your place to others." This may solve the problem of the guilt-ridden person's conscience, but it does not change the ethics of the lifeboat. The needy person to whom the guilt-ridden person yields his place will not himself feel guilty about his good luck. If he did, he would not climb aboard. The net result of conscience-stricken people giving up their unjustly held seats is the elimination of that sort of conscience from the lifeboat.

This is the basic metaphor within which we must work out our solutions. Let us now enrich the image, step by step, with substantive additions from the real world, a world that must solve real and pressing problems of overpopulation and hunger.

The harsh ethics of the lifeboat become even harsher when we consider the reproductive differences between the rich nations and the poor nations. The people inside the lifeboats are doubling in numbers every 87 years; those swimming around outside are doubling, on the average, every 35 years, more than twice as fast as the rich. And since the world's resources are dwindling, the difference in prosperity between the rich and the poor can only increase.

As of 1973, the U.S. had a population of 210 million people, who were increasing by 0.8 percent per year. Outside our lifeboat, let us imagine another 210 million people (say the combined populations of Colombia, Ecuador, Venezuela, Morocco, Pakistan, Thailand and the Philippines), who are increasing at the rate of 3.3 percent per year. Put differently, the doubling time for this aggregate population is 21 years, compared to 87 years for the U.S.

Multiplying the Rich and the Poor

Now suppose the U.S. agreed to pool its resources with those seven countries, with everyone receiving an equal share. Initially, the ratio

of Americans to non-Americans in this model would be one-to-one. But consider what the ratio would be after 87 years, by which time the Americans would have doubled to a population of 420 million. By then, doubling every 21 years, the other group would have swollen to 354 billion. Each American would have to share the available resources with more than eight people.

But, one could argue, this discussion assumes that current population trends will continue, and they may not. Quite so. Most likely the rate of population increase will decline much faster in the U.S. than it will in the other countries, and there does not seem to be much we can do about it. In sharing with "each according to his needs," we must recognize that needs are determined by population size, which is determined by the rate of reproduction which at present is regarded as a sovereign right of every nation, poor or not. This being so, the philanthropic load created by the sharing ethic of the spaceship can only increase.

The Tragedy of the Commons

The fundamental error of spaceship ethics, and the sharing it requires, is that it leads to what I call "the tragedy of the commons." Under a system of private property, the men who own property recognize their responsibility to care for it, for if they don't they will eventually suffer. A farmer, for instance, will allow no more cattle in a pasture than its carrying capacity justifies. If he overloads it, erosion sets in, weeds take over, and he loses the use of the pasture.

If a pasture becomes a commons open to all, the right of each to use it may not be matched by a corresponding responsibility to protect it. Asking everyone to use it with discretion will hardly do, for the considerate herdsman who refrains from overloading the commons suffers more than a selfish one who says his needs are greater. If everyone would restrain himself, all would be well; but it takes only one less than everyone to ruin a system of voluntary restraint. In a crowded world of less than perfect human beings, mutual ruin is inevitable if there are no controls. This is the tragedy of the commons.

One of the major tasks of education today should be the creation of such an acute awareness of the dangers of the commons that people will recognize its many varieties. For example, the air and water become polluted because they are treated as commons. Further growth in the population or per capita conversion of natural resources into pollutants will only make the problem worse. The same holds true for the fish of the oceans. Fishing fleets have nearly disappeared in many parts of the world, technological improvements in the art of fishing are hastening the day of complete ruin. Only the replacement of the system of the commons with a responsible system of control will save the land, air, water and oceanic fisheries.

The World Food Bank

In recent years there has been a push to create a new commons called a World Food Bank, an international depository of food reserves to which nations would contribute according to their abilities and from which they would draw according to their needs. This humanitarian proposal has received support from many liberal international groups, and from such prominent citizens as Margaret Mead, U.N. Secretary General Kurt Waldheim, and Senators Edward Kennedy and George McGovern.

A world food bank appeals powerfully to our humanitarian impulses. But before we rush ahead with such a plan, let us recognize where the greatest political push comes from, lest we be disillusioned later. Our experience with the "Food for Peace program," or Public Law 480, gives us the answer. This program moved billions of dollars worth of U.S. surplus grain to food-short, population-long countries during the past two decades. But when P.L. 480 first became law, a headline in the business magazine Forbes revealed the real power behind it: "Feeding the World's Hungry Millions: How It Will Mean Billions for U.S. Business."

And indeed it did. In the years 1960 to 1970, U.S. taxpayers spent a total of $7.9 billion on the Food for Peace program. Between 1948 and 1970, they also paid an additional $50 billion for other economic aid programs, some of which went for food and food-producing machinery and technology. Though all U.S. taxpayers were forced to contribute to the cost of P.L. 480, certain special interest groups gained handsomely under the program. Farmers did not have to contribute the grain; the Government, or rather the taxpayers, bought it from them at full market prices. The increased demand raised prices of farm products generally. The manufacturers of farm machinery, fertilizers and pesticides benefited by the farmers' extra efforts to grow more food. Grain elevators profited from storing the surplus until it could be shipped. Railroads made money hauling it to ports, and shipping lines profited from carrying it overseas. The implementation of P.L. 480 required the creation of a vast Government bureaucracy, which then acquired its own vested interest in continuing the program regardless of its merits.

Extracting Dollars

Those who proposed and defended the Food for Peace program in public rarely mentioned its importance to any of these special interests. The public emphasis was always on its humanitarian effects. The combination of silent selfish interests and highly vocal humanitarian apologists made a powerful and successful lobby for extracting money from taxpayers. We can expect the same lobby to push now for the creation of a World Food Bank.

However great the potential benefit to selfish interests, it should not be a decisive argument against a truly humanitarian program. We must ask if such a program would actually do more good than harm, not only

momentarily but also in the long run. Those who propose the food bank usually refer to a current "emergency" or "crisis" in terms of world food supply. But what is an emergency? Although they may be infrequent and sudden, everyone knows that emergencies will occur from time to time. A well-run family, company, organization or country prepares for the likelihood of accidents and emergencies. It expects them, it budgets for them, it saves for them.

Learning the Hard Way

What happens if some organizations or countries budget for accidents and others do not? If each country is solely responsible for its own well-being, poorly managed ones will suffer. But they can learn from experience. They may mend their ways, and learn to budget for infrequent but certain emergencies. For example, the weather varies from year to year, and periodic crop failures are certain. A wise and competent government saves out of the production of the good years in anticipation of bad years to come. Joseph taught this policy to Pharaoh in Egypt more than 2,000 years ago. Yet the great majority of the governments in the world today do not follow such a policy. They lack either the wisdom or the competence, or both. Should those nations that do manage to put something aside be forced to come to the rescue each time an emergency occurs among the poor nations?

"But it isn't their fault!" some kindhearted liberals argue. "How can we blame the poor people who are caught in an emergency? Why must they suffer for the sins of their governments?" The concept of blame is simply not relevant here. The real question is, what are the operational consequences of establishing a world food bank? If it is open to every country every time a need develops, slovenly rulers will not be motivated to take Joseph's advice. Someone will always come to their aid. Some countries will deposit food in the world food bank, and others will withdraw it. There will be almost no overlap. As a result of such solutions to food shortage emergencies, the poor countries will not learn to mend their ways, and will suffer progressively greater emergencies as their populations grow.

Population Control the Crude Way

On the average, poor countries undergo a 2.5 percent increase in population each year; rich countries, about 0.8 percent. Only rich countries have anything in the way of food reserves set aside, and even they do not have as much as they should. Poor countries have none. If poor countries received no food from the outside, the rate of their population growth would be periodically checked by crop failures and famines. But if they can always draw on a world food bank in time of need, their population can continue to grow unchecked, and so will their "need" for aid. In the short run, a world food bank may diminish that need, but in the long run, it actually increases the need without limit.

Without some system of worldwide food sharing, the proportion of people in the rich and poor nations might eventually stabilize. The overpopulated poor countries would decrease in numbers, while the rich countries that had room for more people would increase. But with a well-meaning system of sharing, such as a world food bank, the growth differential between the rich and the poor countries will not only persist, it will increase. Because of the higher rate of population growth in the poor countries of the world, 88 percent of today's children are born poor, and only 12 percent rich. Year by year the ratio becomes worse, as the fast-reproducing poor outnumber the slow-reproducing rich.

A world food bank is thus a commons in disguise. People will have more motivation to draw from it than to add to any common store. The less provident and less able will multiply at the expense of the abler and more provident, bringing eventual ruin upon all who share in the commons. Besides, any system of "sharing" that amounts to foreign aid from the rich nations to the poor nations will carry the taint of charity, which will contribute little to the world peace so devoutly desired by those who support the idea of a world food bank.

As past U.S. foreign-aid programs have amply and depressingly demonstrated, international charity frequently inspires mistrust and antagonism rather than gratitude on the part of the recipient nation (see "What Other Nations Hear When the Eagle Screams," by Kenneth J. and Mary M. Gergen, PT, June).

Chinese Fish and Miracle Rice

The modern approach to foreign aid stresses the export of technology and advice, rather than money and food. As an ancient Chinese proverb goes: "Give a man a fish and he will eat for a day; teach him how to fish and he will eat for the rest of his days." Acting on this advice, the Rockefeller and Ford Foundations have financed a number of programs for improving agriculture in the hungry nations. Known as the "Green Revolution," these programs have led to the development of "miracle rice" and "miracle wheat," new strains that offer bigger harvests and greater resistance to crop damage. Norman Borlaug, the Nobel Prize winning agronomist who, supported by the Rockefeller Foundation, developed "miracle wheat," is one of the most prominent advocates of a world food bank.

Whether or not the Green Revolution can increase food production as much as its champions claim is a debatable but possibly irrelevant point. Those who support this well-intended humanitarian effort should first consider some of the fundamentals of human ecology. Ironically, one man who did was the late Alan Gregg, a vice president of the Rockefeller Foundation. Two decades ago he expressed strong doubts about the wisdom of such attempts to increase food production. He likened the growth and spread of humanity over the surface of the earth to the spread of cancer in the human body, remarking that "cancerous growths demand food; but, as far as I know, they have never been cured by getting it."

Overloading the Environment

Every human born constitutes a draft on all aspects of the environment: food, air, water, forests, beaches, wildlife, scenery and solitude. Food can, perhaps, be significantly increased to meet a growing demand. But what about clean beaches, unspoiled forests, and solitude? If we satisfy a growing population's need for food, we necessarily decrease its per capital supply of the other resources needed by men.

India, for example, now has a population of 600 million, which increases by 15 million each year. This population already puts a huge load on a relatively impoverished environment. The country's forests are now only a small fraction of what they were three centuries ago, and floods and erosion continually destroy the insufficient farmland that remains. Every one of the 15 million new lives added to India's population puts an additional burden on the environment, and increases the economic and social costs of crowding. However humanitarian our intent, every Indian life saved through medical or nutritional assistance from abroad diminishes the quality of life for those who remain, and for subsequent generations. If rich countries make it possible, through foreign aid, for 600 million Indians to swell to 1.2 billion in a mere 28 years, as their current growth rate threatens, will future generations of Indians thank us for hastening the destruction of their environment? Will our good intentions be sufficient excuse for the consequences of our actions?

My final example of a commons in action is one for which the public has the least desire for rational discussion--immigration. Anyone who publicly questions the wisdom of current U.S. immigration policy is promptly charged with bigotry, prejudice, ethnocentrism, chauvinism, isolationism or selfishness. Rather than encounter such accusations, one would rather talk about other matters, leaving immigration policy to wallow in the cross-currents of special interests that take no account of the good of the whole, or the interests of posterity.

Perhaps we still feel guilty about things we said in the past. Two generations ago the popular press frequently referred to Dagos, Wops, Polacks, Chinks and Krauts, in articles about how American was being "overrun" by foreigners of supposedly inferior genetic stock (see "The Politics of Genetic Engineering: Who Decides Who's Defective?" PT, June). But because the implied inferiority of foreigners was used then as justification for keeping them out, people now assume that restrictive policies could only be based on such misguided notions. There are other grounds.

A Nation of Immigrants

Just consider the numbers involved. Our Government acknowledges a net inflow of 400,000 immigrants a year. While we have no hard data on the extent of illegal entries, educated guesses put the figure at about 600,000 a year. Since the natural increase (excess of births over deaths)

of the resident population now runs about 1.7 million per year, the yearly gain from immigration amounts to at least 19 percent of the total annual increase, and may be as much as 37 percent if we include the estimate for illegal immigrants. Considering the growing use of birth control devices, the potential effect of educational campaigns by such organizations as Planned Parenthood Federation of America and Zero Population Growth, and the influence of inflation and the housing shortage, the fertility rate of American women may decline so much that immigration could account for all the yearly increase in population. Should we not at least ask if that is what we want?

For the sake of those who worry about whether the "quality" of the average immigrant compares favorably with the quality of the average resident, let us assume that immigrants and nativeborn citizens are of exactly equal quality, however one defines that term. We will focus here only on quantity; and since our conclusions will depend on nothing else, all charges of bigotry and chauvinism become irrelevant.

Immigration vs. Food Supply

World food banks move food to the people, hastening the exhaustion of the environment of the poor countries. Unrestricted immigration, on the other hand, moves people to the food, thus speeding up the destruction of the environment of the rich countries. We can easily understand why poor people should want to make this latter transfer, but why should rich hosts encourage it?

As in the case of foreign-aid programs, immigration receives support from selfish interests and humanitarian impulses. The primary selfish interest in unimpeded immigration is the desire of employers for cheap labor, particularly in industries and trades that offer degrading work. In the past, one wave of foreigners after another was brought to the U.S. to work at wretched jobs for wretched wages. In recent years the Cubans, Puerto Ricans and Mexicans have had this dubious honor. The interests of the employers of cheap labor mesh well with the guilty silence of the country's liberal intelligentsia. White Anglo-Saxon Protestants are particularly reluctant to call for a closing of the door to immigration for fear of being called bigots.

But not all countries have such reluctant leadership. Most educated Hawaiians, for example, are keenly aware of the limits of their environment, particularly in terms of population growth. There is only so much room on the islands, and the islanders know it. To Hawaiians, immigrants from the other 49 states present as great a threat as those from other nations. At a recent meeting of Hawaiian government officials in Honolulu, I had the ironic delight of hearing a speaker, who like most of his audience was of Japanese ancestry, ask how the country might practically and constitutionally close its doors to further immigration. One member of the audience countered: "How can we shut the doors now? We have many friends and relatives in Japan that we'd like to bring here

some day so that they can enjoy Hawaii too." The Japanese-American speaker smiled sympathetically and answered: "Yes, but we have children now, and some day we'll have grandchildren too. We can bring more people here from Japan only by giving away some of the land that we hope to pass on to our grandchildren some day. What right do we have to do that?"

At this point, I can hear U.S. liberals asking: "How can you justify slamming the door once you're inside? You say that immigrants should be kept out. But aren't we all immigrants, or the descendants of immigrants? If we insist on staying, must we not admit all others?" Our craving for intellectual order leads us to seek and prefer symmetrical rules and morals: a single rule for me and everybody else; the same rule yesterday, today and tomorrow. Justice, we feel, should not change with time and place.

We Americans of non-Indian ancestry can look upon ourselves as the descendants of thieves who are guilty morally, if not legally, of stealing this land from its Indian owners. Should we then give back the land to the now living American descendants of those Indians? However morally or logically sound this proposal may be, I, for one, am unwilling to live by it and I know no one else who is. Besides, the logical consequence would be absurd. Suppose that, intoxicated with a sense of pure justice, we should decide to turn our land over the Indians. Since all our other wealth has also been derived from the land, wouldn't we be morally obliged to give that back to the Indians too?

Pure Justice vs. Reality

Clearly, the concept of pure justice produces an infinite regression to absurdity. Centuries ago, wise men invented statutes of limitations to justify the rejection of such pure justice, in the interest of preventing continual disorder. The law zealously defends property rights, but only relatively recent property rights. Drawing a line after an arbitrary time has elapsed may be unjust, but the alternatives are worse.

We are all the descendants of thieves, and the world's resources are inequitably distributed. But we must begin the journey to tomorrow from the point where we are today. We cannot remake the past. We cannot safely divide the wealth equitably among all peoples so long as people reproduce at different rates. To do so would guarantee that our grandchildren, and everyone else's grandchildren, would have only a ruined world to inhabit.

To be generous with one's own possessions is quite different from being generous with those of posterity. We should call this point to the attention of those who, from a commendable love of justice and equality, would institute a system of the commons, either in the form of a world food bank, or of unrestricted immigration. We must convince them if we wish to save at least some parts of the world from environmental ruin.

Without a true world government to control reproduction and the use of available resources, the sharing ethic of the spaceship is impossible. For the foreseeable future, our survival demands that we govern our actions by the ethics of a lifeboat, harsh though they may be. Posterity will be satisfied with nothing less.

LIFEBOAT ETHICS

A REPLY TO HARDIN

by

Janet Besecker

A REPLY TO HARDIN

Garrett Hardin's article ("Lifeboat Ethics: the Case Against Helping the Poor," Psychology Today, September 1974) raises some thorny ethical issues. That his analysis is factually and ethically questionable should not blind us to the debt we owe him for raising these hard questions for discussion.

It is most helpful in understanding Garrett Hardin's case to make explicit his most fundamental assumption. That is that the long-term survival of the species Home sapiens is the ultimate human value, the highest "good." In the interest of this long-term survival Hardin insists that we must not devastate our environment for merely short-run humanitarian desires to save lives. If we do, posterity will suffer. We do not have the right to give away our heritage in this way; it belongs not to us but the future generations. Even more drastically, the rich nations should not give assistance to the poor ones.

What is the world situation according to Hardin? First (but implicitly), the current population is so great that even if the world's resources were distributed equally there would not be enough to support each individual in any degree of dignity.

Second, the survival of the wealthiest nations (as the wealthiest nations, presumably) depends upon their keeping their own surplus to themselves. This surplus is their safety factor in their calculations of supply and demand.

Third, the single most important reason for not sharing even the surplus is that such help could only exacerbate the population problem. Giving aid of the kind that would be available from a world food bank would only increase the population. This would in turn only increase hunger, which could only require more aid, which would, if given, only increase the population, until total catastrophe resulted. Incalculably greater suffering in the long run would be caused by humanitarian aid than by simply letting current starvation and disease weed out the population in the short run.

Fourth, in the past, the giving of aid by the wealthy nations to the poor has been accompanied, not by increased brotherhood, but by intensified animosity between the two sectors of the world. Accepting charity is demeaning and the wealthy nations are not doing anybody any favors by imposing charity on the poor nations. The corollary of this is that the tension between nations would grow more readily through implementing more extensive sharing programs than through cutting off the aid that the wealthy countries now offer.

Fifth, the poor nations could, if they only wanted to badly enough or tried hard enough, do a better job of feeding and limiting their populations. The wealthy nations should not aid them because that help will remove the motivation in the recipient countries to improve their own lot.

To vividly illustrate his point, Hardin uses the analogy of a lifeboat occupied by the wealthy nations (say, 50 people), with only a few places available for the 100 poor people swimming in the ocean and seeking admission. What to do? If those in the lifeboat let all 100 in, then all 150 drown. If just some are let in, the safety factor (i.e., the food reserves) is critically reduced and all in the boat are in danger. Hardin's conclusion: the rich should admit no one else to the lifeboat and they should stand by to repel boarders. Translated into the language of the current world situation: the wealthy nations should not share with the poorer because to do so would endanger the future of the species. We (the wealthy) are not our brothers' keepers. We owe our highest duty to posterity, particularly to our own progeny.

We have tried to carefully state Hardin's case because we wish to refute it in detail. Because of Hardin's considerable reputation, his ideas are reaching a much wider audience than if espoused by an unknown. In our respectful view, his ideas are dangerously wrong--and must be challenged.

We take up that challenge on two fronts. First, we will argue that his facts are suspect and that his application of the "lifeboat analogy" to the current situation is both misleading and counter-productive. Second, we will dispute his ethics.

Let us first deal with Hardin's assertion about the global supply of food. He assumes, although implicitly, that at present the amount of food that could be produced would not reasonably meet the needs of the world's population. The most important point that we want to make here (which will be substantiated below) is that we are not yet in the "lifeboat" situation, but if we were to abide by the advice of policy-maker Hardin, that situation would be inevitable. If the wealthy nations do not act decisively and soon to alleviate the poverty, ignorance and starvation of the poor nations, the world population will grow until its food demands exceed the possible supply. And, just as inevitably, the population will be checked by widespread starvation, disease and violence born of desperation and chaos. The resulting human misery is incalculably enormous and if there is a chance that it can be averted, massive efforts must be made.

Hardin would have us believe that such earnest attempts have been made and that they have failed. This is nonsense. Only token efforts have been made, as is shown by the fact that the balances of trade with, and aid to, the developing nations run in favor of the developed nations.

As we have said, the world community is not yet faced with the "lifeboat" situation. The straits are dire but not that dire. The real problem now is not physical production of food so much as obscene maldistribution of resources which allows obesity and self-indulgence in some parts of the world while people starve elsewhere. Figures recently published indicate that providing food for a world population 10 - 13 times the present one is possible. Admittedly, what is meant here is technologically possible, and we are well aware that high technology agriculture goes hand-in-hand with serious environmental deterioration. But these figures do tell us that we would probably produce enough food to feed the world population during the time it would take, through concentrated effort and sacrifice on the part of the developed nations, to reduce world population growth to zero.

It is our thesis that the ecological damage done by adequately feeding the world's population would be justified on humanitarian grounds, because we believe that population can probably be stabilized well below the threshold of ecological disaster. This goal would necessitate a considerable reduction of ecological depredations by the industrial and manufacturing sector of the world economy, but this is eminently sensible on all fronts.

Second, Hardin totally discounts the effects that an elevated standard of living can have on a population's fertility. The causes of the "demographic transition" are not well understood but it seems clear that as the standard of living rises, as more than just the subsistence needs are met and as literacy increases, a population's fertility declines.

Incontestably, there has been a "demographic transition"--by individual choice--in North America and Europe. We are not suggesting that identical conditions need to be created in the developing world. But we are claiming that when individuals come to appreciate the consequences of high birth rates and when they are financially able to abandon those fertility patterns, they will conclude that having fewer children makes sense. Surely we are entitled to have confidence in the capacity of normal human beings to show the necessary rational self-interest. We don't see how Hardin would justify his assumption that people in the developing world will be incapable of making this decision.

Clearly, the first step in elevating a standard of living is eliminating hunger--nothing can be accomplished until headway is made in this area. But Hardin would have us believe that alleviating hunger inevitably encourage population growth. It is true that, in order for the demographic transition to occur considerably more than just alleviating hunger is required. What is required is not just the elimination of a symptom (in this case, hunger) but a change in the system that produced that symptom. So not just food, but information, capital and many other ingredients go into the necessary development. But it all starts with adequate nourishment.

Hardin seems to believe that advocates of sharing food with the poor advocate shring only food with them. We have said that food is only the beginning step in a process that should culminate in the now dependently poor being able to enjoy dignified and productive lives. In an interdependent world, the goal of "independence" is as anachronistic for the developing countries as it is for the United States.

There is at least one further point on which Hardin is dreadfully wrong. He would have us believe that there is no way in which the wealthy nations could share with the poorer without worsening international relations. He is quite right in that "mistrust and antagonism" were exacerbated by many foreign "aid" ventures. One major reason is that "gratitude" was expected for the "charity." The wealthy nations have made no sacrifices of any sort worthy of the name in the process of aiding foreign countries. The pittances they have allocated to the poor nations have not cut into their excessively high standards of living. Why, indeed, were the poorer countries supposed to be grateful? What is needed is not pious charity born of the need to save some minimal amount of face on the international scene but, instead, an open admission of responsibility on the part of the wealthy nations for the less fortunate. As long as substantial portions of even the paltry sums now allocated to foreign aid go into "bilateral" agreements, in which the recipient nations are forced to buy with the funds goods from the donor country regardless of price, and as long as the motivating force behind foreign "aid" is good returns for the donor country's dollars (or yen, or whatever) "mistrust and antagonism" will be the appropriate responses.

And does Hardin really believe that the poor nations of the world would stand idly by and let the wealthy cut them off from resources and information that are theirs just as much as they are those of the wealthy? As a last ditch effort, surely he realizes that they would resort to violence. India, to name only one, has nuclear weapons. Soon, so will many other of the underdeveloped nations. What are the chances that the species would survive a widespread nuclear war? What will be the extent of the environmental damage of such an event?

And where does Hardin get the idea that the poor nations could be doing much better? We acknowledge the many examples of black marketing of relief food and government corruption in the poor nations. However, to pretend that the elimination of either would overcome the inherent inadequacies of the traditional agricultures of the poor nations is misleading. The wealthy nations are simply not justified in punishing the innocent individual victims of such profiteering and corruption by withholding aid, although the donor nations might be justified in retaining control of the food until the distribution point.

Hardin thus purports to present an "objective" factual dilemma, making prophecies which cannot be proven, and posing an "either-or" situation which, as we have shown, is wide open to factual criticism.

The fact that by massive exertion we may be able to change his gloomy scenario throws doubt on his draconian recommendations.

It is important to remember that in telling us what we the wealthy should do, Hardin is trying to convince us of his ethics. Let us now examine them. He seems to rest his case against helping the poor on three different principles. Because they do not appear to form a coherent ethical system, we will analyze them individually.

Much of his argument is based on utilitarian grounds--in essence, that the greatest good of the greatest number requires that the wealthy keep their wealth for themselves (otherwise unimaginable catastrophe results in the long run). As will be recalled, we believe he is wrong. If so, his utilitarianism reduces, in effect, to a second principle, egoism. We will briefly discuss this second principle, then examine utilitarianism to see if the greatest good of the greatest number would justify Hardin's policies even if he were correct that it would dictate the wealthy's retaining their wealth. Then, we will briefly touch on his third principle.

First, egoism. To the extent that Hardin fails to explain satisfactorily why the presently wealthy have the right to keep their riches, or why equitable redistribution is not possible, his argument collapses into an exhortation to the rich to act in their own self-interest. If his argument is consciously based on this sort of egoism, it is not an ethical argument at all. Any ethical system must offer a means by which conflicting interests are impartially adjudicated. If one group's interest is made the basis of a value system, that system simply is not a morality.

Even if his claim were correct that the rich must remain so if the greatest utilitarian good is to be achieved, do we have to accept his utilitarianism? Not at all. There is always the possibility, when the utilitarian principle is used in an argument, that it may conflict with the principle of justice. This is particularly so in Hardin's argument because in his calculation of the greatest good he sacrifices the welfare of presently alive human beings to the welfare of the as yet unborn.

The principle of justice requires that we treat like individuals alike unless there are morally relevant reasons for discriminating. We find it difficult to see why an individual (particularly one trapped in poverty and ignorant of the systemic implications of his fecundity) deserves to be discriminated against because of his economic status or fecundity. Both are morally irrelevant criteria. However, Hardin recommends that for the sake of the utilitarian good we should discriminate against people according to such parameters. He recommends that we let the poor starve to death today so that fewer in the future will have to do the same. Hardin has said that we cannot both save the starving today and prevent greater starving in the future. We disagree

but let us suppose that there is a high probability he is right. (With respect to such a highly complex issue, there is no basis on which one could dogmatically predict what the future will bring.) Should we then adopt the hands-off policy that Hardin advocates? We don't think so. For suppose we were wrong about the predictions of future populations and had had the resources to save them? Those would be innocent human beings condemned to die for no reason at all, in retrospect. We are reminded of the common lax maxim of justice--it is better to let 99 guilty men go free than to punish one innocent man. There is room for error in predictions about the future, and if we are to err it must be on the side of justice, on the side of those so undeniably alive and hungry today.

Hardin's third principle bears on the survival of the human species. He appears to hold that ensuring species survival should be the primary goal of all individuals and certainly of all responsible governments. But why should survival of the human species be pre-eminent? Surely Hardin would not answer that survival in and of itself was the highest "good." Was it "bad" that the dinosaur became extinct? Is is especially "good" that some beetles have survived almost unchanged for about 200 million years? Ethical evaluations of goods and bads are made by people with reference to their wants and needs. The survival of a species, including a virus disease, is neither good nor bad until we put the beast into our anthropocentric framework. So what meaning does the survival of the human species have for human beings who, after all, must some day cease to exist as individuals?

Would Hardin argue that the perpetuation of the human species was necessary for ecological stability? Again, the concept of ecological stability is meaningless without putting it into a human context. In any case, stability would probably be increased if humankind quite the scene.

One could claim that the potential of enjoying life, of being, of the search for knowledge and understanding of the meaning of life is a noble quest which should continue. But billions of individuals are seeking this goal now, and Hardin's solution would involve the sacrifice of many of them for the sake of a future quest by as yet unborn human beings. Perhaps he would say that this quest, after a short-term genocidal delay, must continue. This is tenable, but we are entitled to weigh the present consequences against future potential. In our view, the price is too high. Why is one future life (or ten) worth ten present ones? The future persons may never be born, i.e., they may never be persons. Do we not have to respect the needs and aspirations of human beings alive today before we sacrifice for as yet non-existent generations?

If the wealthy nations followed Hardin's advice (that virtually anything necessary should be done to ensure the survival of the human race), it is not clear what survival would then signify. In the process

of eliminating conscience from the lifeboat, we are eliminating some of the basic ennobling characteristics which are uniquely human--empathy with others, unselfishness, altruism, giving life a meaning greater than physical survival. We doubt that humanity survives through inhumanity.

Although Hardin repudiates "justice" as dangerous, and although he chooses utility instead of it, he would have us substitute some other content into the box labeled "justice." And what does he propose as the new concept of justice? Nothing but the law of the jungle. Nothing more than might-makes-right. And this amounts to barbarism. The wealthy nations are entitled to their disproportionate fraction of the world's resources (the industrialized nations with 30% of the world's population consume 80% of the energy consumed annually) and, presumably, to their profligate consumption of those resources at an ever increasing rate. Why? His answer must be that this is so because they have them now. Because they have them now, they have the strength to protect them and the strength to secure access to those that they want in the future. Might-makes-right. To say the least, it is an unusual form of "justice."

Hardin seems to believe that the wealthy nations are entitled to the resources of the world because their populations are increasing at a decreasing rate. But their per capita resource consumption is increasing at an increasing rate and shows no more signs of abating than does the Indian population. That exponentially increasing consumption rate dooms the race to eventual catastrophe (e.g., through heat pollution) just as surely as any exponential increase in population.

It has been said that a North American uses 50 times more resources than an Indian. If this is so, then we can calculate that in terms of resource consumption, our continent's population is the stupendous equivalent of 12.25 billion Indians. Even allowing for climatic differences and significant food energy produced for export, can we not imagine the man from Lucknow politely stating that on utilitarian grounds, more human happiness would be achieved if North Americans were thrown overboard and the world were enabled thereby not only to support its present population but perhaps to double it before the problem becomes critical?

So we ask, why were the wealthy nations chosen for the lifeboat? Hardin's overwhelming concern with future generations and his lack of same for human beings alive today are difficult to reconcile. Even if the wealthy nations had played no causal role in the nurturing of population growth rates in the poor countries, and even if they did not become and do not remain wealthy at the expense of these countries, the wealthy would still have to share with the poor to the maximum extent possible. Why? Because we are all fellow human beings with similar sorts of needs that must be met if we are to live dignified and productive lives.

Even if the walthy nations bear no responsibility for having gotten the poor into their predicament, they would still be morally obligated to help the poor <u>out</u> of that predicament. The wealthy do, however, carry a

great deal of the responsibility. It was not until the first quarter of the 20th century that the populations of the underdeveloped countries such as India started to increase rapidly. Medical aid from wealthy countries was used at that time to effectively lower death rates. When the good deeds had been done and "progress" was under way, India and other similar countries were left with a decreased death rate and the same old high birth rate. More babies survived to live longer and often miserable lives. Populations skyrocketed.

It is also true that to a very great extent, the wealth of the wealthy nations (Canada and Australia excepted) depends upon a continual flow of underpriced natural resources from the poor nations. The rich enjoy their standard of living largely because of the exploitation of poor nations. What would Hardin's position be if bauxite, tin, rubber, copper, manganese, nickel, chromium, uranium and oil exports to the United States were cut off because other nations needed them to build "lifeboats"? We suspect that we would hear a great deal about the "mutual interdependence on space ship Earth," or even that the wealthy have the right to use force not only to hoard scarce resources but to acquire them.

We believe that we are not yet in the lifeboat situation and that avoiding the dilemma is possible. But we do have two major reservations about the nature of the events that are going to be required to achieve a world population stabilized at a reasonable level. The first of these two reservations has already been partially explored. We recognize the need to maintain long-term ecological stability and have mentioned the impact of high technology agriculture on such stability. We also recognize man's psychic need for relief from human artifcats, i.e., the need for at least relative wilderness. While we believe that population can be stabilized without precipitating ecological disaster, it is obvious that a trade-off is involved. We cannot retain a pristine environment and solve the global population problem at the same time. But how far should we go down the path of environmental ruin before we call a halt to the process? Surely "the pollution of American rivers is a small price to pay if the alternative is increased starvation in developing countries."

Two consequences of implementing the sharing ethic would reduce the demand for wilderness on the part of the citizens of the wealthy nations. First, a departure from the competitive assumptions that drive our highly developed and wealthy societies in favor of more co-operative assumptions would lessen the anxiety in our lives, and lessen appreciably the compulsive need to "get away from it all." Second, our lowered standard of living, i.e., our decreased disposable incomes, would both reduce our mobility and increase the conviviality of our communities by reducing noise, atmospheric pollution, and irritants of many kinds.

Further consideration must be given to the problem of long-term ecological stability threatened by highly intensive agriculture. It seems

clear that the world's long-term food producing capacity must be considerably increased, but that rushing to the point of ecological collapse is insanity. For various reasons explained above, we believe that the criterion of justice can help to guide our decisions, and that Hardin has presented us with a pseudo-dilemma. It sounds as if he would have use choose the right of one wealthy man and his dog to eat meat while children in Bangladesh starve to death. We hardly need to agonize over that sort of choice.

The second reservation has to do with the potentially disastrous results of development on culture. While the level of development necessary to lower birth rates must be achieved as quickly as possible, one of the limiting factors on the speed at which this process can proceed is the ability of a culture to assimilate the necessary changes. After all, where is the dignity of life without societal context? Human beings do not flourish in vacuums. The richness of life is achieved through interaction with fellow human beings in a coherent pattern of social relations. Insensitive development can shatter lifestyles, but there are alternatives. Intermediate scale technology can be used so that traditional patterns may be kept intact, to the maximum extent possible.

We have said that if the wealthy nations do not change their ways soon it will be too late. We will be led inexorably to the lifeboat crisis--to the point at which, no matter what was done, there would be no way that the world's population could be fed. And what then? At that point academic discussion of the matter would be irrelevant. If the nations of the world are still operating on today's competitive and selfish assumptions, no one will have to exhort the strong and wealthy to protect their interests. One can be sure that that is what they will do, at any cost to the rest of humanity, as that behavior is in keeping with their competitive tradition.

But what if nations tomorrow entered into a truly cooperative venture, the aim of which was to wipe out hunger and lower birth rates, and they failed? What if the best intentions coupled with the best knowledge, technique and insight failed? After all, the extent to which the demographic transition occurs may not be adequate and/or the transition may take too long to occur. What then? Hardin's dilemma then will exist, but if cooperative values have been internalized by the global community then there is a chance that almost universally acceptable criteria for who should live or die could be evolved. And if cooperative values have not been universally internalized, total chaos will ensue, mitigated only by the order imposed by the law of the jungle.

We realize keenly that a prescription of just distribution will not be accepted in our society. There are many regrettable, but understandable reasons for this. We cannot even arouse ourselves to abolish poverty among our own countrymen let alone to implement a foreign aid policy that begins to fulfill our moral obligation to the world's starving. But if anyone says that our conclusions are impractical and therefore

disqualified from serious consideration, we can only grieve that the "is" of our time is so estranged from the "ought" that the latter is found irrelevant.

In Hardin's world, individual lives seem subordinate to an elegant population model based on suspect facts and confused ethics designed primarily to promote the propagation of the human species into eternity. Our position, on the other hand, explicitly subordinates survival to the imperative of justice. The overwhelming good is not our own survival, or even species survival, but equal opportunity for a dignified human life.

Senior Science

Enrichment Modules

EARLY SCIENCE AND THE NATURE OF MATTER

TEACHING HINTS

FOR

EARLY SCIENCE

1. This module may take one or two hours depending on the resources you use.

2. The film, MUSIC OF THE SPHERES, a 50-minute film #510.9, SaskMedia, may be used as an introduction.

3. Have students read the article.

4. Have students complete the worksheet.

5. Additional reference material:

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6. Students should hand in work for evaluation.

STUDENT WORKSHEET

FOR

EARLY SCIENCE

1. Research the meaning of the following words:

Empirical	Motion	Metaphysics
Matter	Zodiac	Affective
Economics	Plenum	

2. List three scientists who embraced the man-made Atomic hypothesis.

3. List three scientists who embraced the man-made Plenum hypothesis.

4. Two main threads of science passed from the Egyptian-Babylonian peoples to the Greek civilization--Astronomy and Geometry. Discuss the use made by the Greeks of both these scientific threads. State clearly which thread was developed most by the early Greeks.

5. Discuss, and then deduce, why science was so involved with religion during early history.

6. The Pythagorean system of the world assumed the earth to move around a "central fire." What evidence would they have for a moving earth system? Was the central fire the sun?

7. Debate Parmenides' position of each real object associated with a definite idea, and that the idea is "more real" than the object.

8. Debate the "full plenum" concept and the "atomic" concept. Try to put yourself into the Greek era and decide which school of thought you would prefer to belong.

9. Research Topics:

    1. The Work of Pythagoras
    2. The Science of Thales
    3. The Work of Democritus
    4. The Garden of Epicurus

Senior Science

Enrichment Modules

EARLY SCIENCE AND THE NATURE OF MATTER

by

Donald Johnson

EARLY SCIENCE AND THE NATURE OF MATTER

Amongst the earliest imprints made by man is an intriguing ancient metaphysical puzzle: "What is it that forever is, but never comes to be? What is it that forever comes to be, but never is?" The puzzle concerns man, science and society and at this moment no solution is to be offered.

Man through his senses and instrumentation receives nature's diverse signals; scientists then attempt to interpret these signals of nature, and in so doing create their own "science." The amount of agreement and correlation between nature's signals and the man-made "science" determines the quality and acceptance of the science. Thus science in this sense is definitely man-made; but what of nature's signals--the reality of things. Does man's science ever exactly duplicate nature's reality? This is the essence of the posed metaphysical puzzle.

By reading about and pondering upon the science of some of humanity's noblest minds, perhaps then, the problem will become most clear and its solution readily available.

The origins of the scientific enterprise may be traced to ancient Egypt and Mesopotamia. To these people science was devoted entirely to practical ends, and the scientists of those days formed a large and well-organized priesthood. It is therefore clear that the roots of science were planted very firmly within the soil of religion. Their science dealt mainly with practical astronomy, elementary geometry applied to surveying, and commercial arithmetic. The technology of the Egyptians may be seen in the tremendous work of the pyramids--a direct application of triangulation. Astronomy was deeply rooted in religion, the sun, moon and five visible planets were recorded and worshiped. The motions of these seven heavenly bodies were believed to affect the affairs of men, and for this reason, the Babylonians especially kept long continued and systematic records of their motions. They also traced the Zodiac, the apparent path of the sun among the stars, and named the twelve signs of the Zodiac.

Astronomy provides an important first thread in the history of science, since the movement of the heavenly bodies presents man with two possible attitudes. One is to observe and record the apparent motions for a long period of time, in order to discover any regularities that there might be and hence future predictions could be attempted. The other attitude is to wonder what the heavenly bodies are actually like and how they are situated in space. As you have seen, the Egyptians and Babylonians accepted the first attitude; it was the Greeks who eventually accepted the latter.

The first scientist of whom we have any knowledge is Thales (640-546 B.C.) of Miletus. Thales had travelled to Egypt and Mesopotamia and brought back to Greece the Babylonian astronomy, tables, and geometry. Thales' main purpose, however, was the desire to explain the universe in which he lived to understand his environment. This is science. It is interesting to note that Thales has been credited historically with making the first eclipse of the sun prediction on May 28, 585 B.C. Thales regarded the entire universe as reducible to water and spirit. These two distinct elements comprised the entire stuff of the world. The earth was a flat disk floating upon a huge surrounding ocean of water.

Due to the Persian wars the Greek intellectual centre moved to Southern Italy, in particular to Syracuse. At this centre Pythagoras settled about 530 B.C. and founded a learned mystical religious society. The Pythagoreans attached supreme importance to numbers and geometry; in fact they assumed the present-day stance of science, that is that the object of science was to reproduce nature by numbers and geometric form. They thought the universe was beautiful because of its order, and originated the "harmony of the spheres." The earth itself was a sphere and it moved around a central fire.

Parmenides (480 B.C.) of Elea continued the traditions of Thales and the Pythagoreans. However, he idealized the relationship between objects of nature and ideas within man; and because nature's objects could sometimes deceive the senses, and hence give a wrong idea, he decided to reject external objects, and instead to put implicit faith into the ideas of man alone. It was Parmenides, amongst others, who extended the universe to four basic elements--Earth, Fire, Water, Air.

One common thread linking all the Greek philosophers mentioned so far was their ultimate belief in a full plenum universe. That is the entire universe is full with something; one object, visible or not, is directly in touch with another object; and, that in the universe there are no gaps. A void, or vacuum, does not exist.

In the fifth century B.C. Leucippus (460 B.C.) of Miletus propounded an Atomic Theory of Matter. Leucippus is certainly credited with the invention of the Atomic Theory although very little is known about him or the theory he actually formulated. More, however, is known about his student Democritus (460-370 B.C.) of Elea and it is from his writings that most of the early atomic theory is drawn.

The Continuous Space Theory (full plenum) of the previous philosophers is replaced by an infinite void, in which are an infinite number of corpuscles of the same primary matter, differing only in shape and size. These corpuscles were called ATOMS from the Greek word for "undivided," and all the atoms are in constant motion. The variety of substances and objects in the world is thus formed by the combination of certain atoms

when they link and attach to one another in a variety of combinations. The space between atoms was of course void, or absolutely nothing--a vaccum must exist for the early atomists.

The atomic theory did not fare well in its early days; only a few people considered the void as a possible hypothesis. The Greek religion of that time considered it "unholy" and completely atheistic as a world-picture of the nature of matter. Besides which, they said, it is not possible to imagine nothing for by that very fact you must automatically think of something! Very little was heard again of the atomic theory of matter until Epicurus (342-270 B.C.) who started a small community in Athens. His school was known as the Garden of Epicurus, and it became noted besides its adherence to the atomic hypothesis, for its moral philosophy and general life style cultivated by the teacher Epicurus.

History has not really been too kind to the Epicureans. In fact most books write with scorn of their philosophy. The Epicureans adopted the first co-educational institution, and whilst their founder demanded a very strict and rigid moral code he also propounded a pleasure principle. It is this latter facet of the entire Epicurean movement that has trickled down through the aeons, with much hidden insinuation. So much so that today an epicure is someone who delights in pleasure; whilst the true Epicurean holds fast to an intellectual ethic.

Senior Science

Enrichment Modules

PLATO, ARISTOTLE AND PTOLEMY

THE WORLD VIEW

TEACHING HINTS

FOR

PLATO, ARISTOTLE AND PTOLEMY

1. This module should take approximately one hour.

2. Have students read the article.

3. Have students complete the worksheet.

4. Let students browse through Aristotle's extracts.

5. Have students discuss the Ptolemaic system sheets.

6. Additional reference material is listed in the EARLY SCIENCE module.

7. Students should hand in work for evaluation.

STUDENT WORKSHEET

ON

PLATO, ARISTOTLE AND PTOLEMY

1. Research the meaning of the following words:

Philosopher	Ether	Syllogisms
Physics	Theorem	Parsimony
Retrograde	Deduction	Paradigm
Trigonometry		

2. Plato, and most Greek scientists, assumed the earth to be fixed and at rest. Discuss and then determine the main reasons for this assumption.

3. Discuss and then explain the difference between Aristotle's two forms of motion.

4. The main point of the Ptolemaic system of the world is that it is mathematical. Discuss and then explain why a mathematical model is useful.

5. A new historical thread of science started by Aristotle was that of motion. His description of motion is not accepted today. Try to determine faults with his system.

6. One passage from Plato's science text Timaeus has caused considerable thought amongst scientists. The passage follows:

> ". . . But earth, our foster-mother, that goes to and fro on her path about the axis of the universe . . . ."

From this passage does Plato believe in a stationary world system? What do you think he means?

7. Aristotelian science relied primarily upon the Deductive Method. Discuss fully this scientific approach.

8. State one intellectual puzzle framed by Plato for his more curious students.

9. Three different schools of thought arose in Athens. State the obvious consequences of such a tripartite situation.

10. Topics for Research:

    1. The Academy of Plato
    2. The Lyceum of Aristotle
    3. The Work of Lucretius
    4. The Work of Archimedes

Senior Science

Enrichment Modules

PLATO, ARISTOTLE AND PTOLEMY

THE WORLD VIEW

by

Donald Johnson

PLATO, ARISTOTLE AND PTOLEMY

THE WORLD VIEW

The views of the Atomists were not only unacceptable to the religious elements of the Greeks, they were also utterly uncongenial to the great philosopher Plato (420-348 B.C.) who lived in Athens and founded the famous "Academy" which endured for nine hundred years. Plato returned to the basic ideas of Parmenides, by suggesting that the real world cannot be apprehended by the senses at all. Plato stressed the importance of man's mind and his highest achievement was to be found in man's pure deductive reasoning and not in the empirical investigations. Science for Plato was simply the contemplation of ideal forms and a study of pure geometry.

The heavens move in a circular motion, therefore, circular motion is perfect. But what of the strange retrograde motion of the wondering planets? Plato suggested that their motion was only an illusion and he posed the question of the solution to all his students, his only limitation being that their answer must be in a form of circular motion. Of course the earth, for Plato and his students, is fixed and at the centre of the universe.

One student of the Academy who eventually surpassed the rest (it should be mentioned that the geometer Euclid was also a student of Plato) was Aristotle (384-322 B.C.). This genius was to affect the entire world-thought of men for many generations. He influenced all departments of thought, not only physics and metaphysics (which really means "after" physics). His system for science purported to describe the entire universe. Unlike Plato his teacher, he accepted the empirical evidence, that is data received by the senses. To such sensory information Aristotle then applied reason in the form of formal logical syllogisms.

Aristotle's world of science was a non-mathematical world of forms and qualities. Matter was, of course, not built up of atoms, the plenum was full. The primary stuff of the universe consisted of five elements--Earth, Fire, Water, Air and the Aether. Motion, for Aristotle, included not only our intuitive idea of movement, but growth, decay and change of quality (example, a change of colour). If something moved something else had to take its place--there was no void (vacuum).

For every motion there must necessarily be someone or something doing the moving. Accordingly, Aristotle divides all motion into two inds--natural motion and enforced motion.

Natural motion includes all living beings which have the mover within themselves and this produces the motion. Falling bodies also undergo natural motion, because they have the quality, or tendency to

fall to the centre of the universe--a heavy object allowed to fall is simply performing its natural motion of moving to the centre of the universe.

Enforced motion concerns thrown bodies and projectiles. When a stone is thrown it is clear where the initial motion comes from--the hand--however, the act of throwing sets a layer of air in motion and transfers a "motive-power" to the next air layer, in such a manner the stone moves onward; each transfer weakens the motive-power and eventually the enforced motion is over, and natural motion moves the stone to the ground.

The universe of Aristotle was a geo-centric system, consisting of a spherical earth at the exact centre of a large sphere of fixed stars. Between the earth and the star-sphere moved the other heavenly bodies in the following order: Moon, Mercury, Venus, Sun, Mars, Jupiter and Saturn.

The earth is the centre due to the nature of natural motion--heavy bodies fall to the centre of the universe and the earth is indeed heavy. Needless to say, the earth was motionless. The heavenly spheres, however, underwent circular motion which was perfect and eternal. To the whole of his universe Aristotle accepts a prime mover, the necessary cause for all the motion.

Aristotle became the scientific authority for the entire world. Argument could be reduced only to and with the formal logic of Aristotle. Like his teacher Plato, Aristotle started his own school in Athens. His school was called the "Lyceum" and he had many successful students.

The Aristotelian picture of the universe underwent a change by Ptolemy (130 A.D.), however, the basic pattern remained Aristotelian. Ptolemy contributed the certainty of mathematics to make the system strong enough to last for another 1500 years.

Ptolemy, of Alexandria, had three major problems to resolve within the Aristotelian model of the universe:

1. The observed variations in brightness of the planets and the moon.

2. The observed differing speeds of the sun, moon, and planets in their orbital paths eastward against the background of the stars.

3. The retrograde motion of the planets--they appear to stop and go west for a while before proceeding on their eastward path, a loop-the-loop.

Ptolemy departed from the view that the earth was the exact centre of the universe. The sun, moon and planets still moved in circular orbits, for perfection, but their centres differed. Their centres were not the centre of the earth; he introduced the equant. The equant could account for the increased brightness and the irregularity of speed. However, in order to explain the retrograde motion of the loop-the-loop, Ptolemy devised the epicycle and deferent. The moon and planets moved in a small circle upon the epicycle; the centre of the epicycle then moved along the deferent around the earth.

Ptolemy's world-system was contained within his book Almagest and in his preface he gives a clear account of his purpose:

> We accordingly thought it up to us so to train our actions even in the application of the imagination as not to forget in whatever things we happen upon the consideration of their beautiful and well-ordered disposition, and to indulge in meditation mostly for the exposition of many beautiful theorems and and especially of those specifically called mathematical . . . .

The Almagest is a beautiful statement of geometry and mathematics, pages of planetary tables and trignometric ratios abound. The accuracy of the Ptolemaic system agreed well with the then known observations; its predictions were excellent for eclipses; but as Ptolemy himself had stated, it was purely a mathematical model. In fact the first major scientific mathematical model developed by man to explain natural scientific phenomena. Aristotle and Ptolemy had devised a comprehensive world-view that was to reign supreme for the next 1500 years.

ARISTOTLE

PHYSICS (PHYSICA)

Translated by

R.P. Hardie and R.K. Gaye

PHYSICS (PHYSICA)

BOOK I

When the objects of an inquiry, in any department, have principles, conditions, or elements, it is through acquaintance with these that knowledge, that is to say scientific knowledge, is attained. For we do not think that we know a thing until we are acquainted with its primary conditions or first principles, and have carried our analysis as far as its simplest elements. Plainly therefore in the science of Nature, as in other branches of study, our first task will be to try to determine what relates to its principles.

The natural way of doing this is to start from the things which are more knowable and obvious to us and proceed towards those which are clearer and more knowable by nature; for the same things are not "knowable relatively to us" and "knowable" without qualification. So in the present inquiry we must follow this method and advance from what is more obscure by nature, but clearer to us, towards what is more clear and more knowable by nature.

Now what is to us plain and obvious at first is rather confused masses, the elements and principles of which become known to us later by analysis. Thus we must advance from generalities to particulars; for it is a whole that is best known to sense-perception, and a generality is a kind of whole, comprehending many things within it, like parts. Much the same thing happens in the relation of the name to the formula. A name, e.g., "round," means vaguely a sort of whole; its definition analyzes this into its particular senses. Similarly a child begins by calling all men "father" and all women "mother," but later on distinguishes each of them.

The principles in question must be either (a) one or (b) more than one.

If (a) one, it must be either (i) motionless, as Parmenides and Melissus assert, or (ii) in motion, as the physicists hold, some declaring air to be the first principle, others water.

If (b) more than one, then either (i) a finite or (ii) an infinite plurality. If (i) finite (but more than one), then either two or three or four or some other number. If (ii) infinite, then either as Democritus believed one in kind, but differing in shape or form; or different in kind and even contrary.

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BOOK II

Of things that exist, some exist by nature, some from other causes.

"By nature" the animals and their parts exist, and the plants and the simple bodies (earth, fire, air, water)--for we say that these and the like exist "by nature."

All the things mentioned present a feature in which they differ from things which are not constituted by nature. Each of them has within itself a principle of motion and of stationariness (in respect of place, or of growth and decrease, or by way of alteration). On the other hand, a bed and a coat and anything else of that sort, quo receiving these designations--i.e., in so far as they are products of art--have no innate impulse to change. But in so far as they happen to be composed of stone or of earth or of a mixture of the two, they do have such an impulse, and just to that extent--which seems to indicate that nature is a source or cause of being moved and of being at rest in that to which it belongs primarily, in virtue of itself and not in virtue of a concomitant attribute.

I say "not in virtue of a concomitant attribute," because (for instance) a man who is a doctor might cure himself. Nevertheless it is not in so far as he is a patient that he possesses the art of medicine; it merely has happened that the same man is doctor and patient--and that is why these attributes are not always found together. So it is with all other artificial products. None of them has in itself the source of its own production. But while in some cases (for instance, houses and the other products of manual labour) that principle is in something else external to the thing, in others--those which may cause a change in themselves in virtue of a concomitant attribute--it lies in the things themselves (but not in virtue of what they are).

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BOOK IV

Since we deny that a void exists, but for the rest the problem has been truly stated, that either there will be no movement, if there is not to be condensation and rarefaction, or the universe will bulge, or a transformation of water into air will always be balanced by an equal transformation of air into water (for it is clear that the air produced from water is bulkier than the water); it is necessary therefore, if compression does exist, either that the next portion will be pushed outwards and make the outermost part bulge, or that some-air, so that the entire bulk of the whole may be equal, or that nothing moves. For when anything is displaced this will always happen, unless it comes round in a circle; but locomotion is not always circular, but sometimes in a straight line.

These then are the reasons for which they might say that there is a void; our statement is based on the assumption that there is a single matter for contraries, hot and cold and the other natural contrarieties, and that what exists actually is produced from a potential existent, and that matter is not separable from the contraries but its being is different, and that a single matter may serve for colour and heat and cold.

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BOOK VI

Zeno's reasoning, however, is fallacious, when he says that if everything when it occupies an equal space is at rest, and if that which is in locomotion is always occupying such a space at any moment, the flying arrow is therefore motionless. This is false, for time is not composed of indivisible moments any more than any other magnitude is composed of indivisibles.

Zeno's arguments about motion, which cause so much disquietude to those who try to solve the problems that they present, are four in number. The first asserts the non-existence of motion on the ground that that which is in locomotion must arrive at the half-way stage before it arrives at the goal. This we have discussed above.

The second is the so-called "Achilles" and it amounts to this, that in a race the quickest runner can never overtake the slowest, since the pursuer must first reach the point whence the pursued started, so that the slower must always hold a lead. This argument is the same in principle as that which depends on bisection, though it differs from it in that the spaces with which we successively have to deal are not divided into halves. The result of the argument is that the slower is not overtaken; but it proceeds along the same lines as the bisection-argument (for in both a division of the space in a certain way leads to the result that the goal is not reached, though the "Achilles" goes further in that it affirms that even the quickest runner in legendary tradition must fail in his pursuit of the slowest), so that the solution must be the same. And the axiom that that which holds a lead is never overtaken is false; it is not overtaken, it is true, while it holds a lead; but it is overtaken nevertheless if it is granted that it traverses the finite distance prescribed. These then are two of his arguments.

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ARISTOTLE

ON THE HEAVENS (DeCAELO)

Translated by

J.L. Stocks

ON THE HEAVENS

BOOK II

It remains to speak of the earth, of its position, of the question whether it is at rest or in motion, and of its shape.

I. As to its position, there is some difference of opinion. Most people--all in fact, who regard the whole heaven as finite--say it lies at the centre. But the Italian philosophers known as Pythagoreans take the contrary view. At the centre, they say, is fire, and the earth is one of the stars, creating night and day by its circular motion about the centre. They further construct another earth in opposition to ours to which they give the name counter-earth. In all this they are not seeking for theories and causes to account for observed facts, but rather forcing their observations and trying to accommodate them to certain theories and opinions of their own. But there are many others who would agree that it is wrong to give the earth the central position, looking for confirmation rather to theory than to the facts of observation. Their view is that the most precious place befits the most precious thing; but fire, they say, is more precious than earth, and the limit than the intermediate, and the circumference and the centre are limits. Reasoning on this basis they take the view that it is not earth that lies at the centre of the sphere, but rather fire. The Pythagoreans have a further reason. They hold that the most important part of the world, which is the centre, should be most strictly guarded, and name it, or rather the fire which occupies that place, the "Guard-house of Zeus," as if the word "centre" were quite unequivocal, and the centre of the mathematical figure were always the same with that of the thing or the natural centre. But is it better to conceive of the case of the whole heaven as analogous to that of animals, in which the centre of the animal and that of the body are different. For this reason, they have no need to be so disturbed about the world, or to call in a guard for its centre; rather let them look for the centre in the other sense and tell us what it is like and where nature has set it. That centre will be something primary and precious; but to the mere position we should give the last place rather than the first. For the middle is what is defined, and what defines it is the limit, and that which contains or limits is more precious than that which is limited, seeing that the latter is the matter and the former the essence of the system.

II. As to the position of the earth, then, this is the view which some advance, and the views advanced concerning its rest or motion are similar. For here too there is no general agreement. All who deny that the earth lies at the centre think that it revolves about the centre, and not the earth only but, as we said before, the counter-earth as well. Some of them even consider it possible that there are several bodies so moving, which are invisible to us owing to the interposition of the earth. This,

they say, accounts for the fact that eclipses of the moon are more frequent than eclipses of the sun; for, in addition to the earth, each of these moving bodies can obstruct it. Indeed, as in any case, the surface of the earth is not actually a centre but distant from it a full hemisphere, there is no more difficulty, they think, in accounting for the observed facts on their view that we do not dwell at the centre, than on the common view that the earth is in the middle. Even as it is, there is nothing in the observations to suggest that we are removed from the centre by half the diameter of the earth. Others, again, say that the earth, which lies at the centre, is "rolled," and thus in motion, about the axis of the whole heaven. So it stands written in the Timaeus.

III. There are similar disputes about the shape of the earth. Some think it is spherical, others that it is flat and drum-shaped. For evidence, they bring the fact that, as the sun rises and sets, the part concealed by the earth shows a straight and not a curved edge, whereas if the earth were spherical the line of section would have to be circular. In this they leave out of account the great distance of the sun from the earth and the great size of the circumference, which, seen from a distance on these apparently small circles appears straight. Such an appearance ought not to make them doubt the circular shape of the earth. But they have another argument. They say that because it is at rest, the earth must necessarily have this shape. For there are many different ways in which the movement or rest of the earth has been conceived.

All of which goes to show not only that the earth is circular in shape, but also that it is a sphere of no great size; for otherwise the effect of so slight a change of place would not be so quickly apparent. Hence one should not be too sure of the incredibility of the view of those who conceive that there is continuity between the parts about the pillars of Hercules and the parts about India, and that in this way the ocean is one. As further evidence in favour of this they quote the case of elephants, a species occurring in each of these extreme regions, suggesting that the common characteristic of these extremes is explained by their continuity. Also, those mathematicians who try to calculate the size of the earth's circumference arrive at the figure 400,000 stades. This indicates not only that the earth's mass is sphereical in shape, but also that as compared with the stars, it is not of great size.

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ARISTOTLE

METAPHYSICS (METAPHYSICA)

Translated by

W.D. Ross

METAPHYSICS

BOOK I

All men by nature desire to know. An indication of this is the delight we take in our senses; for even apart from their usefulness, they are loved for themselves; and above all others the sense of sight. For not only with a view to action, but even when we are not going to do anything, we prefer seeing (one might say) to everything else. The reason is that this, most of all the senses, makes us know and brings to light many differences between things.

By nature animals are born with the faculty of sensation, and from sensation memory is produced in some of them, though not in others. And therefore the former are more intelligent and apt at learning than those which cannot remember; those which are incapable of hearing sounds are intelligent though they cannot be taught, e.g., the bee, and any other race of animals that may be like it; and those which besides memory have this sense of hearing can be taught.

The animals other than man live by appearances and memories, and have but little of connected experience; but the human race lives also by art and reasonings. Now from memory experience is produced in men; for the several memories of the same thing produce finally the capacity for a single experience. And experience seems pretty much like science and art, but really science and art come to men through experience; for "experience made art," as Polus says, "but inexperience luck." Now art arises when from many notions gained by experience, one universal judgment about a class of objects is produced. For to have a judgment that when Callias was ill of this disease this did him good, and similarly in the case of Socrates and in many individual cases, is a matter of experience; but to judge that it has done good to all persons of a certain constitution, marked off in one class, when they were ill of this disease, e.g., to phlegmatic or bilious people when burning with fever--this is a matter of art.

Since we are seeking this knowledge, we must inquire of what kind are the causes and the principles, the knowledge of which is Wisdom. If one were to take the notions we have about the wise man, this might perhaps make the answer more evident. We suppose first, then, that the wise man knows all things, as far as possible, although he has not knowledge of each of them in detail; secondly, that he who can learn things that are difficult, and not easy for man to know, is wise (sense-perception is common to all, and therefore easy and no mark of Wisdom); again, that he who is more exact and more capable of teaching the causes is wiser, in every branch of knowledge; and that of the sciences, also, that which is desirable on its own account and for the sake of knowing it is more of

the nature of Wisdom than that which is desirable on account of its results, and the superior science is more of the nature of Wisdom than the ancillary; for the wise man must not be ordered but must order, and he must not obey another, but the less wise must obey him.

ARISTOTLE

NICOMACHEAN ETHICS (ETHICA NICOMACHEA)

Translated by

W.D. Ross

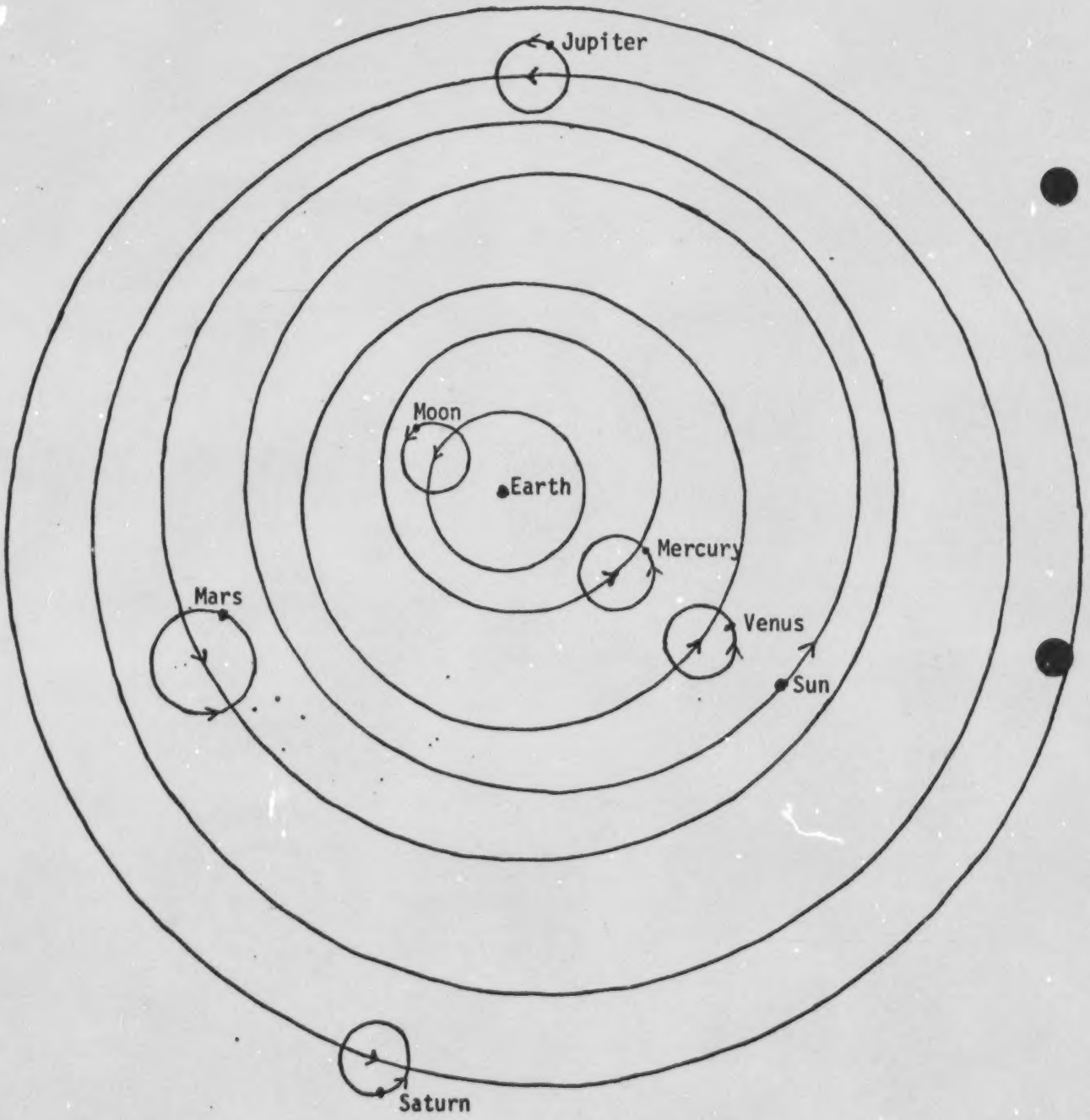
NICOMACHEAN ETHICS

BOOK I

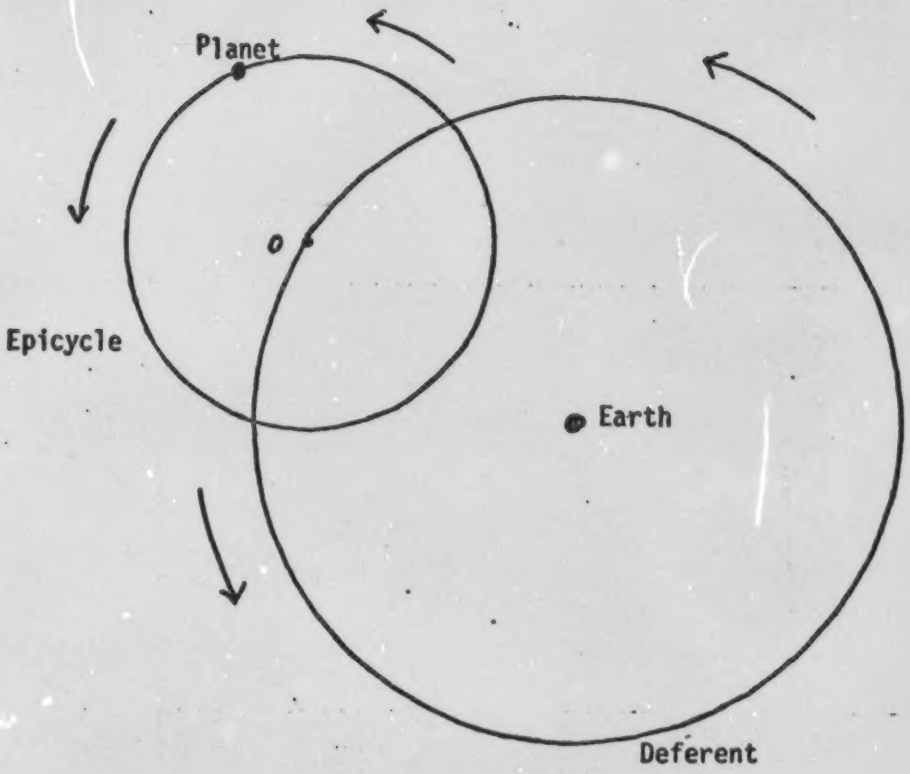
1. Every art and every inquiry, and similarly every action and pursuit, is thought to aim at some good; and for this reason the good has rightly been declared to be that at which all things aim. But a certain difference is found among ends; some are activities, others are products apart from the activities that produce them. Where there are ends apart from the actions, it is the nature of the products to be better than the activities. Now, as there are many actions, arts, and sciences, their ends also are many; the end of the medical art is health, that of shipbuilding a vessel, that of strategy victory, that of economics wealth. But where such arts fall under a single capacity--as bridle-making and other arts concerned with the equipment of horses fall under the art of riding, and this and every military action under strategy, in the same way other arts fall under yet others--in all of these the ends of the master arts are to be preferred to all the subordinate ends; for it is for the sake of the former that the latter are pursued. It makes no difference whether the activities themselves are the ends of the actions, or something else apart from the activities, as in the case of the sciences just mentioned.

2. If, then, there is some end of the things we do, which we desire for its own sake (everything else being desired for the sake of this), and if we do not choose everything for the sake of something else (for at that rate the process would go on to infinity, so that our desire would be empty and vain), clearly this must be the good and the chief good. Will not the knowledge of it, then, have a great influence on life? Shall we not, like archers who have a mark to aim at, be more likely to hit upon what is right? If so, we must try, in outline at least to determine what it is, and of which of the sciences or capacities it is the object. It would seem to belong to the most authoritative art and that which is most truly the master art. And politics appears to be of this nature; for it is this that ordains which of the sciences should be studied in a state, and which each class of citizens should learn and up to what point they should learn them; and we see even the most highly esteemed of capacities to fall under this, e.g., strategy, economics, rhetoric; now, since politics uses the rest of the sciences, and since, again, it legislates as to what we are to do and what we are to abstain from, the end of this science must include those of the others, so that this end must be the good for man. For even if the end is the same for a single man and for a state, that of the state seems at all events something greater and more complete whether to attain or to preserve; though it is worth while to attain the end merely for one man, it is finer and more godlike to attain it for a nation or for city-states. These, then, are the ends at which our inquiry aims, since it is political science, in one sense of that term.

PTOLEMAIC SYSTEM



PTOLEMAIC SYSTEM



Senior Science

Enrichment Modules

COPERNICUS

(1473-1543)

TEACHING HINTS
FOR
COPERNICUS

1. This module should take approximately one hour.

2. Have students read the article.

3. Briefly discuss the star charts with the students, and show them how to plot α and δ.

4. Have students complete the worksheet.

5. Additional reference material:

Armitage, Angus. Copernicus. New York: T. Yoseloff, 1957.

Johnson, D. Man Science Society. Saskatoon, 1974.

Kuhn, Thomas S. The Copernicean Revolution. Cambridge: Harvard University Press, 1957.

Rosen, Edward. Three Copernicean Treatises. New York: Columbia Press, 1939.

6. Have students hand in work for evaluation.

STUDENT WORKSHEET

ON

COPERNICUS

1. Plot the position of either Mercury or Mars using the following data. Join all points in succession with a smooth line (Note: α = Horizontal axis; δ = Vertical axis)

	MERCURY			MARS		
Date	α		δ	α		δ
Sept. 23	13^h	15^m	-12°	7^h	25^m	23°
Oct. 8	12	40	- 6			
Oct. 23	12	45	- 3	8	35	20
Nov. 7	14	5	-11			
Nov. 22	15	40	-20	9	20	17
Dec. 7	17	20	-25			
Dec. 22	19	0	-25	9	50	16
Jan. 6	20	25	-20	9	50	17
Jan. 21	20	0	-17	9	35	19
Feb. 5	19	30	-20			
Feb. 20	20	30	-19	8	50	22
Mar. 7	21	55	-15			
Mar. 22	23	35	- 5	8	35	22
Apr. 6	1	20	+ 8	8	35	22
Apr. 21	3	5	+20	9	0	20
May 6	3	50	+22			
May 21	3	30	+17	9	45	15
June 5	3	25	+15			
June 20	4	20	+19	10	45	9
July 5	6	10	+24			
July 20	8	25	+21	11	45	2
Aug. 4	10	15	+12			
Aug. 19	11	30	+ 2			

2. Compare the orbits of the two planets.

3. Note the relative position of the planet's paths, the sun's path, and the positions of the zodiac. Discuss why such great emphasis was placed on the effect of the position of heavenly bodies on the affairs of men.

Senior Science

Enrichment Modules

COPERNICUS

by

Donald Johnson

COPERNICUS

Nicolaus Copernicus was born February 19, 1473, in the town of Thorn, Poland. His father was successful in the wholesale trade in the major city of Cracow; his mother was semi-aristocratic and of very wealthy parents. Nicolaus was the youngest of four children and when their father died in 1484, the mother did not refuse the offer by Father Lucas Watzelrode, the children's uncle, to adopt the four Copernicean children.

Father Watzelrode was a wise and considerate guardian and decided quite early that Nicolaus should be educated for the priesthood. The good Father was honoured by the Pope in 1489, being made the Bishop of Ermeland, and hence moved to live in the episcopal palace at Heilsburg.

Nicolaus Copernicus, at the age of eighteen, entered the University of Cracow. There he devoted himself to the study of mathematical science and theology. He studied at Cracow for three years and was influenced by one of his teachers, Albert Brudzewski, who was especially learned in mathematics, astronomy and humanistic studies.

In 1493, after consulting with his uncle Bishop Watzelrode, Copernicus went to Italy--the most advanced cultural centre in the world at that time. There he attended the University of Bologna, where he followed a course in Church Law. It was during this time that Copernicus met the learned Platonist, Domenico Navara. Navara, a geometer and astronomer par excellence, was intrigued by the variations observed in the orbitals of the moon and the five planets. He was working feverishly trying to fit Ptolemy's epicycles together, so that the geometry and observed facts would fit together perfectly. Copernicus caught Navara's enthusiasm and together they worked at the geometry of cycles and epicycles.

During a visit to Heilsbury in 1497 Copernicus was appointed Canon of the Cathedral in Frauenburg. His thirst for knowledge was such, however, that he almost immediately applied to the Bishop--Uncle Watzelrode--for a leave from his canonical duties in order to pursue his (theological) studies. He returned to Italy late in 1497, and achieved some limited acclaim to the extent that he was invited to lecture upon mathematics in Rome.

In 1501, Copernicus received a further extension of leave from his canonical duties; this time he desired to pursue the study of medicine at Padua, Italy. His studies proceeded from 1501-1505 at the famous medical school in Padua. However, for one year 1503, Copernicus studied and completed his doctor of theological law degree at Ferrara University in Italy.

When Copernicus eventually returned to his native Poland in 1506, he was not only a humanist learned in Greek and Latin, the languages of scholars, but also in mathematics, astronomy, law and medicine. To say the least, Copernicus was a complete man of learning and capability.

From 1506-1512, Copernicus resided at the episcopal palace in Heilsburg as personal physician to his uncle, the Bishop. It was during these years that Copernicus thought about and wrote of his heliocentric system for the solar system. He looked to the Pythagoreans for help in the solution for the errors found in Ptolemy's geocentric explanations.

In 1512 the Bishop died and Copernicus at last moved to Frauenburg to take up his post as Canon of the cathedral. By 1513 most of his hypotheses for the heliocentric system were settled; he had reached the stage where he needed experimental evidence to either support or refute his thesis. This stage, of gathering information, took until 1529--a sixteen-year experiment!

The reputation of Copernicus was not of course restricted to the mathematical sciences. In 1514, the Pope invited Copernicus to the Lateran Council discussions, which were, at that time, considering the alteration of the calendar. Copernicus declined the invitation on the grounds that the movements of the sun and moon had not yet been determined with sufficient accuracy, and hence no useful purpose could be achieved concerning discussions of the calendar at that time.

In 1530 Copernicus felt confident enough of his heliocentric theory, based upon his and other astronomers' observations verifying the same, that he published a short outline of the theory. It immediately attracted great attention. In Rome, Albrecht Widmanstadt lectured upon the new Copernicean doctrine; Pope Clement VII gave his tentative approval to one of the faithful; and a prominent Cardinal asked Copernicus to publish a complete account of his theory.

Copernicus refused all entreaties to publish his complete work until 1539 when a Joachim Rheticus, a young professor from Germany, received permission to publish a general account called Narratio Prima. Towards the end of 1542, Copernicus finally gave permission for the publication of the entire work--De Revolutionibus Orbium Coelestium or "The Revolutions of the Heavenly Spheres."

The book was published in Nuremburg in 1543. However, Copernicus never did see his published work, for he was seized with apoplexy and paralysis in December 1542 and when the first printed edition of his book arrived at his home in Frauenburg, he was in a deep coma and never recovered. In fact the book arrived on the very same day upon which Copernicus died--May 24, 1543. Copernicus was buried with due pomp and ceremony in Frauenburg Cathedral.

The Copernicean hypothesis contained with De Revolutionbus opposed the existing paradigm of Ptolemy. Copernicus maintained that the world (meaning the entire universe) was indeed spherical as was assumed by Plato. Similarly, the celestial bodies--the planets--did move in perfect circular orbits about the sun. However, the earth was also in orbit around the sun--it was just another planet of the heavens.

Copernicus illustrated the earth's sphericity by discussing travellers moving north and south upon its surface. When they move so, they see differing constellations (star patterns) in the sky. Besides which Copernicus discussed the dipping of a ship's mast below the horizon when sailing out of port. Such examples, argued Copernicus, must lead to the assumption that the earth is indeed a sphere--like the other celestial bodies.

His heliocentric system placed the sun at the centre of the entire celestrial domain. Radiant, central and immutable. The planet Mercury orbited closest to the sun and it moved in a circular path, taking 88 days to complete its orbit. Next came Venus with a periodicity of 7-1/2 months. The earth, followed by its own orbiting moon, proceeded next around the sun upon its annual orbit. Mars with its 2-year period; Jupiter with its 12-year period; Saturn with its 30-year period, followed in order. Finally, the immobile sphere of the fixed stars came last of all.

Copernicus noted a threefold motion of the earth:

1. The first motion of the earth is the circuit of day and night, due to the motion around the axis of the earth from west to east.

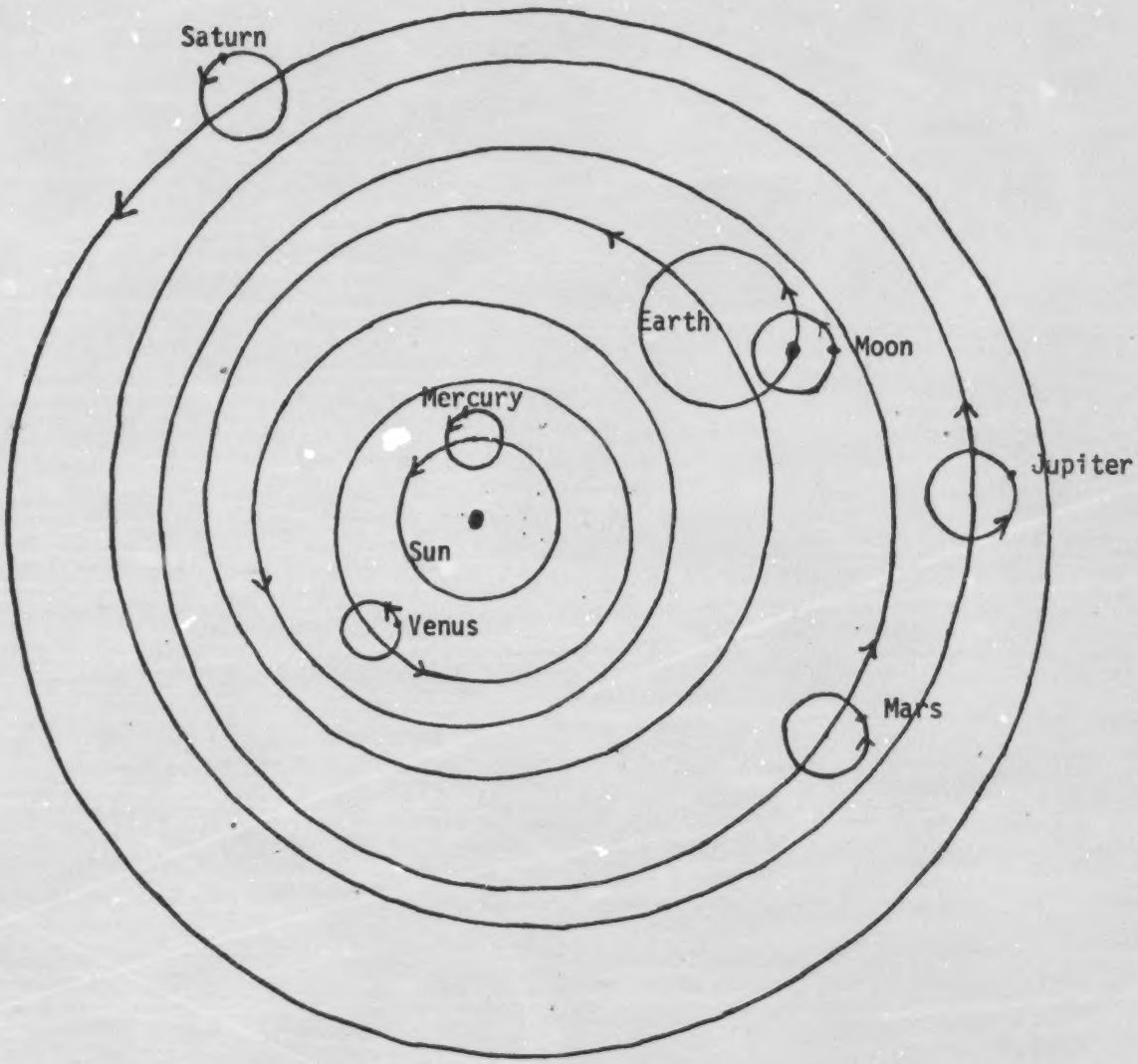
2. The second motion is the annual movement of the planet earth which describes a circle of the zodiac signs around the sun from west to east.

3. The third motion involves declination; it is also an annual motion. By declination, Copernicus understood the tilting of the earth's axis, thus producing earth's differing seasons.

The Copernicean heliocentric system was a precise, detailed mathematical model. Similarities to the Ptolemaic model were obvious--Copernicus still utilized the equant, cycles and epicycles. However, the major concept of his system differed radically by placing the earth in orbit about an immutable sun. The earth became just another mere planet. Copernicus's thoroughness, however, helped to provide an alternative to the prevailing scientific paradigm; an alternative which essentially underlined the parsimony principle inherent in science.

However, scientific ideas do not gain, and never have gained, instant recognition. The ideas were novel and interesting, but that was all. Any fool could tell by simple experience, that whilst the mathematical principles underlying the hypothesis were sound, the earth did not move. The Copernicean revolution must wait for a further 150 years before society would accept the strange new phenomena of a moving earth.

COPERNICAN SYSTEM



Senior Science

Enrichment Modules

GALILEO

(1564 - 1642)

TEACHING HINTS

FOR

GALILEO

1. This module could take up to three hours.

2. There are two good introductory films:

   STARRY MESSENGER, a 50-minute film #520.9, SaskMedia

   GALILEO: A CHALLENGE OF REASON, a 30-minute film

3. Have students read THE STARRY MESSENGER.

4. Have students read TWO NEW SCIENCES.

5. Have students complete the worksheet.

6. Additional references:

Drake, Stillman. Discoveries and Opinions of Galileo. New York: Doubleday Co., 1957.

Galilei, Galileo. Dialogue Concerning the Two Chief World Systems. Translated by S. Drake. Berkeley: University of California Press, 1953.

Galilei, Galileo. Dialogues Concerning Two New Sciences. Translated by H. Crew. New York: Macmillan Co., 1914.

Johnson, D. Man Science Society. Saskatoon, 1974.

King, Henry C. The History of the Telescope. London: Griffin and Co. Ltd., 1955.

Rosen, Edward. The Naming of the Telescope. New York: Abelard-Schuman, 1947.

Santillana, Giorgio. The Crime of Galileo. Chicago: University Press, 1955.

7. Students should hand in work for evaluation.

STUDENT WORKSHEET

ON

GALILEO

1. In Galileo's The Starry Messenger, what is the invention to which Galileo is referring?

2. The Moon had always been considered a "heavenly body." How did Galileo's discovery change this?

3. Galileo in The Starry Messenger refers to four new "wandering" stars.

   (a) What name would you give instead of "wandering" stars?

   (b) What are they in fact?

4. Do you think Galileo was a religious man? Use examples to substantiate your response.

5. Galileo's mechanics was written in his book Two New Sciences.

   (a) Name the Aristotelian character in the book.

   (b) Name the new-view scientist.

   (c) Name the open-minded character.

   (d) Point out Galileo's wit in the above names.

6. What did Galileo's major argument about falling objects depend upon?

7. Galileo touches upon the limitations of experiment science. Use quotations to illustrate this limitation.

8. A contemporary of Galileo's named Bruno was burnt at the stake in 1600 for believing in the Copernicean system. Debate the position of Bruno in not recanting and that of Galileo in recanting the Copernicean system for the moving earth. Pay attention to each's moral position, and the esteem of colleagues.

GALILEO GALILEI

(1638)

TWO NEW SCIENCES

TWO NEW SCIENCES

Galileo's early writings on mechanics (the study of the behavior of matter under the influence of forces) were in the tradition of the standard medieval theories of physics, although he was aware of some of the shortcomings of those theories. During his mature years his chief interest was in astronomy. However, when his important astronomical book, Dialogue on the Two Great World Systems (1632), was condemned by the Roman Catholic Inquisition and he was forbidden to teach the "new" astronomy, Galileo decided to concentrate again on mechanics. This work led to his book Discourses and Mathematical Demonstrations Concerning Two New Sciences Pertaining to Mechanics and Local Motion (1638), usually referred to as Two New Sciences. This treatise signaled the beginning of the end, not only of the medieval theory of mechanics, but also of the entire Aristotelian cosmology which it supported.

Galileo was old, sick, and nearly blind at the time he wrote Two New Sciences. Yet, as in all his writings, his style is spritely and delightful. He used the dialogue form to allow a lively conversation among three "speakers": Simplicio, who competently represents the Aristotelian view; Salviati, who presents the new views of Galileo; and Sagredo, the uncommitted man of good will and open mind, eager to learn. Eventually, of course, Salviati leads his companions to Galileo's views. Let us listen to Galileo's three speakers as they discuss the problem of free fall:

> Salviati: I greatly doubt that Aristotle ever tested by experiment whether it is true that two stones, one weighing ten times as much as the other, if allowed to fall at the same instant from a height of, say, 100 cubits, would so differ in speed that when the heavier had reached the ground, the other would not have fallen more than 10 cubits. [A "cubit" is equivalent to about 20 inches.]
>
> Simplicio: His language would indicate that he had tried the experiment, because he says: We see the heavier; now the word see shows that he had made the experiment.
>
> Sagredo: But, I, Simplicio, who have made the test can assure you that a cannon ball weighing one or two hundred pounds, or even more, will not reach the ground by as much as a span [hand-breadth] ahead of a musket ball weighing only half a pount, provided both are dropped from a height of 200 cubits.

Here, perhaps, one might have expected to find a detailed report on an experiment done by Galileo or one of his colleagues. Instead, Galileo uses a "thought experiment"--an analysis of what would happen in an imaginary experiment--to cast grave doubt on Aristotle's theory of motion:

Salviati: But, even without further experiment, it is possible to prove clearly, by means of a short and conclusive argument, that a heavier body does not move more rapidly than a lighter one provided both bodies are of the same material and in short such as those mentioned by Aristotle. But tell me, Simplicio, whether you admit that each falling body acquires a definite speed fixed by nature, a velocity which cannot be increased or diminished except by the use of violence or resistance?

Simplicio: There can be no doubt but that one and the same body moving in a single medium has a fixed velocity which is determined by nature and which cannot be increased except by the addition of impetus or diminished except by some resistance which retards it.

Salviati: If then we take two bodies whose natural speeds are different, it is clear that on uniting the two, the more rapid one will be partly retarded by the slower, and the slower will be somewhat hastened by the swifter. Do you not agree with me in this opinion?

Simplicio: You are unquestionably right.

Salviati: But if this is true, and if a large stone moves with a speed of, say, eight, while a smaller moves with a speed of four, then when they are united, the system will move with a speed less than eight; but the two stones when tied together make a stone larger than that which before moved with a speed of eight. Hence the heavier body moves with less speed than the lighter one; an effect which is contrary to your supposition. Thus you see how, from your assumption that the heavier body moves more rapidly than the lighter one, I infer that the heavier body moves more slowly.

Simplicio: I am all at sea. . . . This is, indeed, quite beyond my comprehension. . . .

Simplicio retreats in confusion when Salviati shows that the Aristotelian theory of fall is self-contradictory. But while Simplicio cannot refute Galileo's logic, his own eyes tell him that a heavy object does fall faster than a light object:

Simplicio: Your discussion is really admirable; yet I do not find it easy to believe that a birdshot falls as swiftly as a cannon ball.

Salviati: Why not say a grain of sand as rapidly as a grindstone? But, Simplicio, I trust you will not follow the example of many others who divert the discussion from

its main intent and fasten upon some statement of mine that lacks a hairsbreadth of the truth, and under this hair hide the fault of another that is as big as a ship's cable. Aristotle says that "an iron ball of one hundred pounds falling from a height of 100 cubits reaches the ground before a one-pound ball has fallen a single cubit." I say that they arrive at the same time. You find, on making the experiment, that the larger outstrips the smaller by two fingerbreadths. . . . Now you would not hide behind these two fingers the 99 cubits of Aristotle, nor would you mention my small error and at the same time pass over in silence his very large one.

GALILEO GALILEI

(1610)

THE STARRY MESSENGER

THE STARRY MESSENGER

Great indeed are the things which in this brief treatise I propose for observation and consideration by all students of nature. I say great, because of the excellence of the subject itself, the entirely unexpected and novel character of these things, and finally because of the instrument by means of which they have been revealed to our senses.

Surely it is a great thing to increase the numerous host of fixed stars previously visible to the unaided vision, adding countless more which have never before been seen, exposing these plainly to the eye in numbers ten times exceeding the old and familiar stars.

It is a very beautiful thing, and most gratifying to the sight, to behold the body of the moon, distant from us almost sixty earthly radii, as if it were no farther away than two such measures--so that its diameter appears almost thirty times larger, its surface nearly nine hundred times, and its volume twenty-seven thousand times as large as when viewed with the naked eye. In this way, one may learn with all the certainty of sense evidence that the moon is not robed in a smooth and polished surface but is in fact rough and uneven, covered everywhere, just like the earth's surface, with huge prominences, deep valley, and chasms.

Again, it seems to me a matter of no small importance to have ended the dispute about the Milky Way by making its nature manifest to the very senses as well as to the intellect. Similarly it will be a pleasant and elegant thing to demonstrate that the nature of those stars which astronomers have previously called "nebulous" is far different from what has been believed hitherto. But what surpasses all wonders by far, and what particularly moves us to seek the attention of all astronomers and philosophers, is the discovery of four wandering stars not known or observed by any man before us. Like Venus and Mercury, which have their own periods about the sun, these have theirs about a certain star that is conspicuous among those already known, which they sometimes precede and sometimes follow, without ever departing from it beyond certain limits. All these facts were discovered and observed by me not many days ago with the aid of a spyglass which I devised, after first being illuminated by divine grace. Perhaps other things, still more remarkable, will in time be discovered by me or by other observers with the aid of such an instrument, the form and construction of which I shall first briefly explain, as well as the occasion of its having been devised. Afterwards I shall relate the story of the observations I have made.

Senior Science

Enrichment Modules

NEWTON

(1642-1727)

TEACHING HINTS

FOR

NEWTON

1. This module may take one or two hours depending on which resources are used.

2. Show the film, NEWTON: THE MIND THAT FOUND THE FUTURE, a 20-minute film #921, SaskMedia.

3. Have students complete film notes while watching the film.

4. Have students complete the worksheet.

5. Allow students to browse through Newton's extracts.

6. Additional references:

Andrade, E.N. Sir Isaac Newton. New York: Doubleday, 1958.

Cohen, I.B. Franklin and Newton. Philadelphia: A.P.S., 1956.

Cohen, I.B. and Schofield, R.E. Isaac Newton's Papers and Letters. Cambridge: University Press, 1958.

Johnson, D. Man Science Society. Saskatoon, 1974.

More, L.T. Isaac Newton. New York: Scribner and Sons, 1934.

Newton, Isaac. Mathematical Principles of Natural Philosophy. Translated by Andrew Motte. London: Dawsons, 1968.

Newton, Isaac. Opticks. New York: Dover Publications, 1952.

Taylor, Sherwood F. Science Past and Present. London: W. Heinemann Ltd., 1949.

7. Students should hand in work for evaluation.

FILM NOTES

ON

NEWTON: THE MIND THAT FOUND THE FUTURE

1. Who was the narrator of the film?

2. Make a note of Pope's famous Newtonian quotation.

3. Describe Newton's scientific methods.

4. State one of Newton's scientific enemies.

5. Describe Newton's experiments concerned with colour.

6. Name Newton's major book.

STUDENT WORKSHEET

ON

NEWTON

1. How did Edmund Halley help Newton with his work on the Law of Universal Gravitation?

2. There are two ways of approaching a science problem stated in the film:

   (1) Use a hypothesis first and then either prove or disprove it.

   (2) Experiment first and obtain the facts, then hypotheses to explain the facts.

   (a) Which method does Newton suggest is the best way for science?

   (b) Give an example from the film to illustrate him using this method.

3. What is a prism? How did Newton's use of one result in a new theory of light?

4. What part of Newton's work did Robert Hooke and the Royal Society reject? Why?

5. "Give me a mountain high enough, and a cannon powerful enough, and I will put an apple into orbit around the earth like the moon." Draw a sketch to illustrate Newton's quotation.

ISAAC NEWTON

THE MATHEMATICAL PRINCIPLES OF NATURAL PHILOSOPHY

(PRINCIPIA)

Translated by

Andrew Motte

BOOK I

Definition I: The quantity of matter is the measure of the same, arising from its density and bulk conjunctly.

Definition II: The quantity of motion is the measure of the same, arising from the velocity and quantity of matter conjunctly.

Definition III: The Vis Insita, or Innate Force of Matter, is a power of resisting, by which every body, as much as in it lies, endeavours to persevere in its present state, whether it be of rest, or of moving forward in a right line.

Definition IV: An impressed force is an action exerted upon a body in order to change its state, either of rest, or of moving uniformly forward in a right line.

Definition V: A centripetal force is that by which bodies are drawn or impelled, or any way tend, towards a point as to a centre.

Definition VI: The absolute quantity of a centripetal force is a measure of the same, proportional to the efficacy of the cause that propagates it from the centre, through the spaces round about.

Definition VII: The accelerative quantity of a centripetal force is a measure of the same, proportional to the velocity which it generates in a given time.

Definition VIII: The motive quantity of a centripetal force, is the measure of the same, proportional to the motion which it generates in a given time.

As the order of the parts of Time is immutable, so also is the order of the parts of Space. Suppose those parts to be mov'd out of their places, and they will be mov'd (if the expression may be allowed) out of themselves. For times and spaces are, as it were, the Places as well of themselves as of all other things. All things are placed in Time as to order of Succession; and in Space as to order of Situation. It is from their essence or nature that they are Places; and that the primary places of things should be moveable, is absurd. These are therefore the absolute places; and translations out of those places, are the only Absolute Motions.

But because the parts of Space cannot be seen, or distinguished from one another by our Senses, therefore in the stead we use sensible

measures of them. For from the positions and distances of things from any body consider'd as immoveable, we define all places; and then with respect to such places, we estimate all motions, considering bodies as transfer'd from some of those places into others. And so instead of absolute places and motions, we use relative ones; and that without any inconvenience in common affairs; but in Philosophical disquisitions, we ought to abstract from our senses, and consider things themselves, distinct from what are only sensible measures of them. For it may be that there is no body really at rest, to which the places and motions of others may be referr'd.

But we may distinguish Rest and Motion, absolute and relative, one from the other by their Properties, Causes and Effects. It is a property of Rest, that bodies really at rest do rest in respect of one another. And therefore as it is possible, that in the remote regions of the fixed Stars, or perhaps far beyond them, there may be some body absolutely at rest; but impossible to know from the position of bodies to one another in our regions, whether any of these do keep the same position to that remote body; it follows that absolute rest cannot be determined from the position of bodies in our regions.

Law I: Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon.

Law II: The alteration of motion is ever proportional to the motive force impressed and is made in the direction of the right line in which that force is impressed.

Law III: To every Action there is always opposed an equal Reaction; or the mutual actions of two bodies upon each other are always equal, and directed to contrary parts.

BOOK III

THE SYSTEM OF THE WORLD

In the preceding books I have laid down the principles of philosophy; principles, not philosophical, but mathematical; such to wit, as we may build our reasonings upon in philosophical enquiries. These principles are, the laws and conditions of certain motions, and powers or forces, which chiefly have respect to philosophy. But lest they should have appeared of themselves dry and barren, I have illustrated them here and there, with some philosophical scholiums, giving an account of such things, as are of more general nature, and which philosophy seems chiefly to be founded on; such as the density and resistance of bodies, spaces void

of all bodies, and the motion of light and sounds. It remains, that from the same principles, I now demonstrate the frame of the System of the World. Upon the subject, I had indeed composed the third book in a popular method, that it might be ready by many. But afterwards considering that such as had not sufficiently entered into the principles, could not easily discern the strength of the consequences, nor lay aside the prejudices to which they had been many years accustomed; therefore to prevent the disputes which might be raised upon such accounts, I chose to reduce the substance of that book into the form of propositions (in the mathematical way) which should be read by those only, who had first made themselves masters of the principles established in the preceding books. Not that I would advise any one to the previous study of every proposition of those books. For they abound with such as might cost too much time, even to readers of good mathematical learning. It is enough if one carefully reads the definitions, the laws of motion, and the first three sections of the first book. He may then pass on the this book, of the System of the World and consult such of the remaining propositions of the first two books, as the references in this, and his occasions, shall require.

Rule I: We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances.

Rule II: Therefore to the same natural effects we must, as far as possible, assign the same causes.

Rule III: The qualities of bodies, which admit neither intension nor remission of degrees, and which are found to belong to all bodies within the reach of our experiments, are to be esteemed the universal qualities of all bodies whatsoever.

Rule IV: In experimental philosophy we are to look upon propositions collected by general induction from phenomena as accurately or very nearly true, notwithstanding any contrary hypotheses that may be imagined, till such time as other phenomena occur by which they may either be made more accurate, or liable to exceptions.

Every man, so far as he is a thing that has perception, is one and the same man during his whole likfe, in all and each of his organs of sense. God is the same God, always and everywhere. He is omnipresent, not virtually only, but also substantially; for virtue cannot subsist without substance. In him are all things contained and moved, yet neither affects the other: God suffers nothing from the motion of bodies; bodies find no resistance from the omnipresence of God. 'Tis allowed by all that the supreme God exists necessarily; and by the same necessity he exists always and everywhere. Whence also he is all similar, all eye, all ear, all brain, all arm, all power to perceive, to understand and to act;

but in a manner not at all human, in a manner not at all corporeal, in a manner utterly unknown to us. As a blind man has no idea of colours, so have we no idea of the manner by which the all-wise God perceives and understands all things. He is utterly void of all body and bodily figure, and can therefore neither be seen, nor heard, nor touched; nor ought he to be worshipped under the representation of any corporeal thing. We have ideas of his attributes, but what the real substance of any thing is, we know not. In bodies we see only their figures and colours, we hear only the sounds, we touch only their outward surfaces, we smell only the smells, and taste the savours; but their inward substances are not to be known, either by our senses, or by any reflex act of our minds; much less then have we any idea of the substance of God. We know him only by his most wise and excellent contrivances of things, and final causes; we admire him for his perfections; but we reverence and adore him on account of his dominion. For we adore him as his servants; and a God without dominion, providence, and final causes, is nothing else but Fate and Nature. Blind metaphysical necessity, which is certainly the same always and every where, could produce no variety of things. All that diversity of natural things which we find, suited to different times and places, could arise from nothing but the ideas and will of a Being, necessarily existing. But by way of allegory, God is said to see, to speak, to laugh, to love, to hate, to desire, to give, to receive, to rejoice, to be angry, to fight, to frame, to work, to build. For all our notions of God are taken from the ways of mankind, by a certain similitude which, though not perfect, has some likeness however. And thus much concerning God; to discourse of whom from the appearance of things, does certainly belong to Natural Philosophy.

Hitherto we have explain'd the phenomena of the heavens and of our sea, by the power of Gravity, but have not yet assign'd the cause of this power. This is certain, that it must proceed from a cause that penetrates to the very centers of the Sun and Planets, without suffering the least diminution of its force; that operates, not according to the quantity of the surfaces of the particles upon which it acts (as mechanical causes use to do), but according to the quantity of the solid matter which they contain, and propagates its virtue on all sides, to immense distances, decreasing always in the duplicate proportion of the distances. Gravitation towards the Sun, is made up out of the gravitations towards the several particles of which the body of the Sun is compos'd; and in receding from the Sun, decreases accurately in the duplicate proportion of the distances, as far as the orb of Saturn, as evidently appears from the quiescence of the aphelions of the Planets; nay, and even to the remotest aphelions of the Comets, if those aphelions are also quiescent. But hitherto I have not been able to discover the cause of those properties of gravity from Phenomena, and I frame no hypotheses. For whatever is not deduc'd from the phenomena, is to be called an hypothesis; and hypotheses, whether metaphysical or physical, whether of occult qualities or mechanical, have no place in experimental philosophy. In this philosophy particular propositions are inferr'd from the phenomena, and afterwards render'd general by induction. Thus it was that the impenetrability, the mobility, and the impulsive force of bodies, and the laws of motion

and of gravitation, were discovered. And to us it is enough, that gravity does really exist, and act according to the laws which we have explained, and abundantly serves to account for all the motions of the celestial bodies, and of our se.

And now we might add something concerning a certain most subtle Spirit, which pervades and lies hid in all gross bodies; by the force and action of which Spirit, the particles of bodies mutually attract one another at near distances, and cohere, if contiguous; and electric bodies operate to greater distances, as well repelling as attracting the neighbouring corpuscles; and light is emitted, reflected, refracted, inflected, and heats bodies; and all sensation is excited, and the members of animal bodies move at the command of the will, namely, by the vibrations of this Spirit, mutually propagated along the solid filaments of the nerves, from the outward organs of sense to the brain, and from the brain into the muscles. But these are things that cannot be explain'd in few words, nor are we furnish'd with that sufficiency of experiments which is required to an accurate determination and demonstration of the laws by which this electric and elastic spirit operates.

PROPOSITION VI. THEOREM VI.

That all bodies gravitate towards every Planet; and that the Weights of bodies towards any the same Planet, at equal distances from the centre of the Planet, are proportional to the quantities of matter which they severally contain.

It has been, now of a long time, observed by others, that all sorts of heavy bodies (allowance being made for the inequality of retardation, which they suffer from a small power of resistance in the air) descend to the Earth from equal heights in equal times; and that equality of times we may distinguish to a great accuracy, by the help of pendulums. I tried the thing in gold, silver, lead, glass, sand, common salt, wood, water, and wheat. I provided two wooden boxes, round and equal. I filled the one with wood, and suspended an equal weight of gold (as exactly as I could) in the centre of oscillation of the other. The boxes hanging by equal threads of 11 feet, made a couple of pendulums perfectly equal in weight and figure, and equally receiving the resistance of the air. And placing the one by the other, I observed them to play together forwards and backwards, for a long time, with equal vibrations. And therefore the quantity of matter in the gold (by cor. I. and 6., prop. 24, book 2) was to the quantity of matter in the wood, as the action of the motive force (or vis motrix) upon all the gold, to the action of the same upon all the wood; that is, as the weight of the one to the weight of the other. And the like happened in the other bodies. By these experiments, in bodies of the same weight, I could manifestly have discovered a difference of matter less than the thousandth part of the whole, had any such been. But, without all doubt, the nature of gravity towards the Planets, is the same as towards the Earth. For, should we

imagine our terrestrial bodies removed to the orb of the Moon, and there, together with the Moon, deprived of all motion, to be let go, so as to fall together towards the Earth; it is certain, from what we have demonstrated before, that, in equal times, they would describe equal spaces with the Moon, and of consequence are to the Moon, in quantity of matter, as their weights to its weight. Moreover, since the satellites of Jupiter perform their revolutions in times which observe the sesquiplicate proportion of their distances from Jupiter's centre, their accelerative gravities towards Jupiter will be reciprocally as the squares of their distances from Jupiter's centre; that is, equal, at equal distances. And therefore, these satellites, if supposed to fall towards Jupiter from equal heights, would describe equal spaces in equal times, in like manner as heavy bodies do on our Earth. And by the same argument, if the circumsolar Planets were supposed to be let fall at equal distances from the Sun, they would, in their descent towards the Sun, describe equal spaces in equal times. But, forces, which equally accelerate unequal bodies, must be as those bodies; that is to say, the weights of the Planets towards the Sun must be as their quantities of matter. Further, that the weights of Jupiter and of his satellites towards the Sun are proportional to the several quantities of their matter, appears from the exceeding regular motions of the satellites (by cor. 3, prop. 65, book I). For if some of those bodies were more strongly attracted to the Sun in proportion to their quantity of matter than others, the motions of the satellites would be disturbed by that inequality of attraction (by cor. 2, prop. 65, book I). If, at equal distances from the Sun, any satellite in proportion to the quantity of its matter, did gravitate towards the Sun, with a force greater than Jupiter in proportion to his, according to any given proportion, suppose of d to e, then the distance between the centres of the Sun and of Jupiter, nearly in the subduplicate of that proportion; as by some computations I have found. And if the satellite did gravitate towards the Sun with a force, lesser in the proportion of e to d, the distance of the centre of the satellite's orb from the Sun, would be less than the distance of the centre of Jupiter from the Sun, in the subduplicate of the same proportion. Therefore if, at equal distances from the Sun, the accelerative gravity of any satellite towards the Sun were greater or less than the accelerative gravity of Jupiter towards the Sun, by one 1/1000 part of the whole gravity; the distance of the centre of the satellite's orbit from the Sun would be greater or less than the distance of Jupiter from the Sun, by one 1/2000 part of the whole distance; that is, by a fifth part of the distance of the utmost satellite from the centre of Jupiter; an excentricity of the orbit which would be very sensible. But the orbits of the satellites are concentric to Jupiter, and therefore the accelerative gravities of Jupiter, and of all its satellites towards the Sun, are equal among themselves. And by the same argument, the weights of Saturn and of his satellites, towards the Sun, at equal distances from the Sun, are as their several quantities of matter; and the weights of the Moon and of the Earth towards the Sun, are either none, or accurately proportional to the masses of matter which they contain. But some they are by cor. I and 3, prop. 5.

But further, the weights of all the parts of every Planet towards any other Planet, are one to another as the matter in the several parts. For if some parts did gravitate more, others less, than for the quantity of their matter; then the whole Planet, according to the sort of parts with which it most abounds, would gravitate more or less, than in proportion to the quantity of matter in the whole. Nor is it of any moment, whether these parts are external or internal. For, if, for example, we should imagine the terrestrial bodies with us to be raised up to the orb of the Moon, to be there compared with its body. If the weights of such bodies were to the weights of the external parts of the Moon, as the quantities of matter in the one and in the other respectively; but to the weights of the internal parts, in a greater or less proportion, then likewise the weights of those bodies would be to the weight of the whole Moon, in a greater or less proportion; against what we have shewed above.

COR. I. Hence the weights of bodies do not depend upon their forms and textures. For, if the weights could be altered with the forms, they would be greater or less, according to the variety of forms in equal matter; altogether against experience.

COR. 2. Universally, all bodies about the Earth gravitate towards the Earth; and the weights of all, at equal distances from the Earth's centre, are as the quantities of matter which they severally contain. This is the quality of all bodies, within the reach of our experiments; and therefore (by rule 3), to be affirmed of all bodies whatsoever. If the aether, or any other body, were either altogether void of gravity, or were to gravitate less in proportion to its quantity of matter, then, because (according to Aristotle, Des Cartes, and others), there is no difference betwixt that form, it might be changed at last into a body of the same condition with those which gravitate most in proportion to their quantity of matter; and, on the other hand, the heaviest bodies, acquiring the first form of that body, might by degrees, quite lose their gravity. And therefore the weights would depend upon the forms of bodies, and with those forms might be changed, contrary to what was proved in the preceding corollary.

COR. 3. All spaces are not equally Full. For if all spaces were equally full, then the specific gravity of the fluid which fills the region of the air, on account of the extreme density of the matter, would fall nothing short of the specific gravity of quick-silver, or gold, or any other the most dense body; and therefore, neither gold, nor any other body, could descend in air. For bodies do not descend in fluids, unless they are specifically heavier than the fluids. And if the quantity of matter in a given space, can, by any rarefaction, be diminished, what should hinder a dimunution to infinity?

COR. 4. If all the solid particles of all bodies are of the same density, nor can be rarified without pores a void space or vaccum must be granted. By bodies of the same density, I mean those, whose vires inertia are in the proportion of their bulks.

COR. 5. The power of gravity is of a different nature from the power of magnetism. For the magnetic attraction is not as the matter attracted. Some bodies are attracted more by the magnet, others less; most bodies not at all. The power of magnetism, in one and the same body, may be increased and diminished; and is sometimes far stronger, for the quantity of matter than the power of gravity; and in receding from the magnet, decreases not in the duplicate, but almost in the triplicate proportion of the distance, as nearly as I could judge from some rude observations.

Senior Science

Enrichment Modules

RELATIVITY

TEACHING HINTS

FOR

RELATIVITY

1. The time for this module could be either one or two hours depending upon which resources you wish to use.

2. The film, THE MAJESTIC CLOCKWORK, a fifty-minute film, #530.1, SaskMedia could be used as an introduction.

3. Have the students read the article on relativity.

4. Have the students complete the worksheet.

5. Useful resource books are:

Baker, A. Modern Physics and Antiphysics. Don Mills: Adison-Wesley, 1970.

Coleman, J. Relativity for the Layman. New York: Mentor Books, 1960.

Einstein, A. On the Electrodynamics of Moving Particles. Translated by Saha and Bose. Cambridge: University Press, 1920.

Einstein, A. The Principle of Relativity. Translated by Perrett and Jeffrey. New York: Dover, 1958.

Einstein, A. The Meaning of Relativity. Princeton: University Press, 1969.

Gamow, A. Biography of Physics. New York: Harper and Row, 1961.

6. Students should hand in work for evaluation.

STUDENT WORKSHEET

ON

RELATIVITY

1. Research the meaning of the following words:

Postulates	Dilation	Geodesic	Apodeictic
Absolutes	Synchronous	Criterion	Concatenate
Immanent	Inertia	Coordinates	

2. Debate the reasonableness of nature's speed limit, $c = 3 \times 10^8$ m/sec.

3. State the names of four people who contributed to the Ether concept.

4. State two results of the Michelson-Morley experiment.

5. Consider two synchronous clocks A and B. If clock A is moved to B at a speed of c/2 and takes 1 second to accomplish the trip, determine the time difference between the two clocks.

6. Consider the following relativistic addition of velocities situation:

   (a) Both bodies are travelling in the same direction at the same speed c/2.

   (b) Both bodies are travelling in the same direction at the same speed c.

   Calculate the net relative velocity for each case.

7. Use the relativistic mass equation to calculate the mass of a moving body relative to its rest mass, under the following conditions:

   (a) The mass is moving at a speed c/2.

   (b) The mass is moving at a speed c.

8. Einstein also formulated the conversion equation between matter and energy: $E = mc^2$ where E is the energy measured in Joules; m is the mass in kilograms; and c is the speed of light, 3×10^8 m/sec. Calculate the energy output obtainable by converting:

   (a) 1 g of matter

   (b) 1 ton of matter (approximately 1000 kg)

9. Debate the merits of Absolute Truth vs. Relative Truth, as a consequence of Einstein's theory.

10. Topics for Research:

1. The geometry of Euclid
2. The geometry of Riemann
3. The details of the Michelson-Morley experiment
4. The history of measuring the velocity of light
5. The electromagnetic work of J.C. Maxwell
6. The recent cosmological work of Hubble

FILM NOTES

ON

THE MAJESTIC CLOCKWORK

1. Kepler

2. Newton

   (a) Early Life

   (b) Calculus

   (c) Universal Gravitation

   (d) Optiks

(e) "Wild Character"

(f) Satire and Criticisms

(g) Absolutes

2. Einstein

(a) Michelson-Morley Experiment

(b) Early Problem

(c) Effects of High Speed

(d) Einstein and God

Senior Science

Enrichment Modules

RELATIVITY

by

Donald Johnson

RELATIVITY

The impact of the relativity theory upon the foundations of society has been subtle and yet all pervading. That such a seemingly harmless novelty during 1905 should shake the very body politic to such an extent is, perhaps, due to our very proximity to the event in time.

The unfolding drama of relativity began, as we have seen with Galileo. It continued when Ole Roemer obtained the first reasonable estimate of the velocity of light in 1675--Roemer obtained his value by observing the time needed for the orbit of one of the moons of Jupiter. Huygen's undulatory theory of light assumed, of necessity, the all-pervading Ether, upon which the light waves could be propagated. Mendeleev, in his first periodic table of elements, placed the element Ether at the beginning of his table with atomic number zero. Maxwell, by integrating electricity and magnetism into electromagnetic waves, and illustrating that light was also electromagnetic in nature, reinforced the Ether concept. Finally, the discovery of the polarization effects of light assured the undulatory model and the Ether became a definite attribute of nature, necessary for the propagation of all electromagnetic waves.

The Ether concept became a necessity, and the characteristic properties of the Ether postulated:

1. That it pervaded all of the space of the known universe;
2. That it have no determinate mass; and thus no "drag" effects upon the movements of the planets;
3. That it is absolutely at rest with respect to all components of the universe;
4. That it permits all electromagnetic phenomena to propagate immanently through it.

In 1881, A.A. Michelson devised and conducted an experiment to measure the velocity of light relative to the static Ether. His results were discouraging. In 1887, with Morley in Cleveland, Michelson tried again having refined and substantiated the procedures. Their result produced the famous Michelson-Morley Experiment. Basically, their experiment consisted of having two beams of light travelling the same distances, but at right angles to one another. Their purpose was to show the effect of the moving earth system through the Ether. The light beam moving with the earth would have a net relative velocity of $(c + v)$, where c is the velocity of light and v is the velocity of the earth. Similarly, another beam would have a net relative velocity of $(c - v)$. The whole affair may

compared to a man walking at 5 m.p.h. upon a train travelling at 60 m.p.h. When the man walks to the front of the train, his net velocity will be (60 + 5) = 65 m.p.h. relative to the ground; when walking to the rear of the train his net velocity will be (60 - 5) = 55 m.p.h.

The entire Michelson-Morley apparatus could be rotated, and tested at different times of the year--enabling different orientations of the earth within the Ether. Their entire theory and predictions were sound; however, their results yielded the same null effect as in 1881: That absolutely no motion of the earth relative to the Ether could be detected; the velocity of light remained constant regardless of the motion of the source. [In the above example, (c + v) = c; and (c - v) = c.]

The negative result of the Michelson-Morley experiment produced a few interesting novelties, one of which was the Lorentz-Fitzgerald Contraction: They argued that a necessary consequence of the experiment was a contraction of length in the direction of motion for any fast moving object! The amount of contraction would depend solely upon the velocity of the moving object, and if the object moved at the velocity of light (c), then the object would have disappeared in one dimension! The weird world of relative motion had arrived. The velocity of light became nature's speed limit; nothing, it seemed, could travel faster than the velocity of light, and if moving objects approached this limit, then of necessity, strange things happened.

In 1905, Albert Einstein published his Special Relativity Theory in the journal, Annalen der Physik, 17. Einstein considered the consequences of the Michelson-Morley experiment, and reached the conclusion that the assumption of the Ether—"lighäther"--was completely superfluous. However, Einstein replaced this assumption with two of his own:

1. That all coordinate systems for mechanical equations were equivalent.

2. That light is propagated in vacant space with a velocity c, which is independent of the nature of motion of the emitting body.

By considering synchronous events occurring along two rods, one at rest, the other moving with a velocity v, Einstein obtained a "shortening" ratio of $\frac{1}{\sqrt{\frac{1-v^2}{c^2}}}$.

This ratio increases in size as v gets larger. For v = c, all moving bodies shrink in planes; while having v > c becomes meaningless and, hence, the velocity of light (c) plays the role of an infinite speed. Einstein further illustrated that a moving clock loses an amount of $\frac{1}{2} \cdot \frac{v^2}{c^2}$

per second of motion; hence, with moving clocks time appears slower than with a stationary clock. This apparent slower rate of time of a moving system relative to a stationary system is called the Time Dilation Effect.

To illustrate the effect, consider two identical clocks at points A and B. Each clock records exactly the same time when situated at the respective positions--they are synchronous clocks. Now if clock A is moved to point B, then the clocks will no longer be synchronous; clock A will lag behind clock B by an amount of $\frac{1}{2}\frac{c^2}{v^2}$ t, where t is the time for the trip. In a faster moving clock, time is slower; so that a clock at the equator must be slower by a small amount than a similarly constructed clock which is situated at the pole.

Einstein's Special Relativity Theory besides dealing with length contractions, and time dilations, also considered the relativistic additions of velocities and obtained:

$$v = \frac{v_1 + v_2}{1 + v_1 \cdot \frac{v_2}{c^2}}$$

Where v_1 and v_2 are the respective velocities of any two bodies, and v is their net relative velocity. Finally, Einstein considered the apparent paradox of a body being continuously accelerated according to Newton's Second Law of Motion, and yet never able to supercede the velocity of light. Einstein showed that the only way to make sense of this situation was to consider that the mass of the body must increase with its speed in such a way as to make its acceleration less and less for the higher speeds. In fact, the mass "m" of a moving body is related to "m_o" its "rest mass" by:

$$m = \frac{m_o}{\sqrt{1 - \frac{v^2}{c^2}}} .$$

In 1914 Einstein published his General Theory of Relativity due to his concern with the fundamental principle of inertia. Classical mechanics indeed showed, and the experiments of Eötvos had verified the basic equivalence of inertial and gravitational mass.

The empirical fact of this principle of equivalence is simple: that the inertial mass of a body measured by the ratio of the applied force to the bodies accompanying acceleration; and the same bodies gravitational mass measured by the gravitational attractive force. These

quantities are in fact equal, i.e., $\frac{m_1}{m_2} = 1$.

This basic equivalence of necessity equates acceleration with gravity. In fact, gravitational forces and effects may be considered as acceleration modes. Indeed, in an accelerating spaceship the effects produced would be as if a gravitational force were acting.

If a rectangle is stationary, then a light ray OA would travel in the straight line path illustrated by OA. However, if the entire rectangle was accelerating upwards, then due to the finite speed of light, a light ray from O would require some time to reach the end at A; during this time interval, the point A would obviously have risen, and some point below A would now be in a corresponding collinear position with the original emitting light source. Therefore, the ray of light emitted within the accelerating rectangle would undergo a graviation-like bending; whilst to an outside observer, the motion would seem collinear.

Due to the equivalence of acceleration and gravity, Einstein predicted that for a star close to the sun, the light from a star reaching the earth should undergo bending similar to the accelerating rectangle illustration. In fact, Einstein predicted 1.7 seconds of arc displacement for such a star. In 1919, during an eclipse of the sun, precisely 1.7 seconds of arc was observed for a star.

Einstein had shown, in effect, that the universe of space was curved due to the presence of large celestial bodies. That while, in imagination, the shortest distance between points is a straight line, in actual fact the real path is a geodesic. Therefore, light rays passing throughout the universe are bent out of collinear paths due to the gravitational fields of stars and celestial matter in general.

The entire geometry of the imagined straight line principles, derived by Euclid and promulgated throughout the ages, conditions and controls our entire thinking and concatenations. The influence of gravitating bodies and the finite speed of light, both of necessity postulate the geodesic and curved space. Since all our observations of either stars, galaxies, quasars or pulsars depend upon the propagation and reception of light, or some form of electromagnetic radiation and, all of which, as has been seen, is influenced and curved by the intervening gravitating bodies.

In order to better comprehend the nature of the universe, Einstein utilized the geometry of Riemann--a geometry of curved space. Riemann developed his geometry after disagreeing with one basic postulate of Euclid, the postulate involving parallel lines.

The Euclidean space presents the ordinary triangle; naturally in this linear space, the sum of the three angles of the triangle is 180°.

The positive curvature, illustrates a triangle only this time the sides are constructed upon a sphere, and since upon a sphere the shortest distance between two points is not a straight line but a geodesic, the sum of the three angles will be larger than 180°. This fact is the basic characteristic of a positively curved space.

Negative curvature characterizes a "saddle" space. In such a space the lines of the triangle bend inwards, and the three angles of the triangle in this type of space are less than 180°.

Thus, Riemann presents a definite criterion for space identification. If $A + B + C = 180°$, then space will be Euclidean (or, as Einstein called it, Galilean); if $A + B + C > 180°$, then space will be curved with a positive curvature; if $A + B + C < 180°$, then space will be curved with a negative curvature.

Einstein proved conclusively the necessary nature of space due to the presence of gravitating bodies. Besides the confirmation of the 1919 observations, Einstein's general theory gave the first accurate computation of the planet Mercury's perihelion. His logic and brute facts are undeniable. Einstein deduced as a necessary consequence of his general theory that in fact space and the universe are finite; and that a "big bang," occurring approximately 1.5×10^9 years ago, did in fact produce this finite universe.

Einstein's four dimensional space-time--with coordinates (x, y, z, ict) consisting of the usual three space coordinates and the fourth time coordinate introduced because of the presence of gravitational fields--thus rules and measures the entire finite universe.

It is, perhaps, strange and surprising to realize that such subtle physical principles involved within Special and General Relativity should have any direct impact, or effect upon society as a whole; yet the relativity principle is found to undermine our present-day mode of thought. The abandonment of absolute value systems is readily apparent: Truth becomes only a relative value, a substituted working hypothesis; many people today would accept no apodeictic truths, but would suggest that things are merely relative; that change and adaptation are merely the necessary requirements for life itself. Einstein's theory of relativity has changed man's basic beliefs.

Senior Science

Enrichment Modules

TWENTY WAYS THE WORLD COULD END

TEACHING HINTS

FOR

TWENTY WAYS THE WORLD COULD END

1. This module should take approximately one hour.

2. Give the students thirty minutes for reading and discussion.

3. Have students complete the worksheets.

4. Some useful audio-visual ideas may be found in DIMENSIONS OF CHANGE, Sunburst Communications, and in HUMAN VALUES IN AN AGE OF TECHNOLOGY, The Center for Humanities Inc.

5. Students should had in work for evaluation.

STUDENT WORKSHEET

ON

TWENTY WAYS THE WORLD COULD END

1. What are the chances of the world coming to an end?

2. Do you agree with Dr. Asimov's idea about the "Real Disaster"? Explain.

3. (a) How do you think the general public reacts to articles like this?

   (b) What can be done about this?

4. Choose any two possible disasters, other than famine, that might occur and discuss the consequences.

5. Try to list more possible ways the world could end.

6. What can/should we do about these problems?

7. Given this information about doomsday prophesies, what do <u>you</u> propose to do?

Senior Science

Enrichment Modules

TWENTY WAYS THE WORLD COULD END

by

Isaac Asimov

TWENTY WAYS THE WORLD COULD END

Are we living on a doomed planet? If one decides the world has a beginning, then surely it must have an ending, too. Generally, if it is thought the world began not very long ago, it is natural to suppose it should come to an end not very long from now.

The somber mythology of the Norsemen saw an end to the world that was not to be long delayed, for instance. There would come Ragnarok, the Twilight of the Gods. When the gods and heroes would march out to meet their deadly enemies, the giants and monsters, in the last climactic battle that would destroy the world.

Similarly, the Bible, which tells of the beginning of heaven and earth in the first book of the Old Testament, speaks of the end, too, in Revelation, the last book of the New Testament. It tells of a climactic battle at Armageddon and a final Day of Judgment.

The Bible does not give the actual time of the Day of Judgment, but the early Christians appear to have expected it to come soon since the Savior had appeared and completed His mission. The end did not come, but in each generation there were those who proclaimed it imminent.

The year 1000 brought panic to some Christians who took the Revelation's reference to the 1000 years that preceded the end to mean the 1000 years that had just passed. When the end did not come, other calculations were made--over and over.

In the 1830s, a New York farmer, William Miller, calculated the end would come in 1843 and many people sold all they had, donned white robes, and waited on hilltops. Nothing happened, but the movement gave rise to the Adventists, who still wait.

In 1879, Jehovah's Witnesses came into being as an offshoot of the Adventists and they waited for an imminent end. They still wait. They are still sure it is imminent.

Others have expected more secular ends. Comets have always been feared as omens of disaster and destruction. As late as 1910, when Halley's Comet made its most recent appearance, uncounted numbers feared that Earth would be destroyed in its passing. Just a few years ago, there were amusing mystics who predicted that the passing of the small planetoid, Icarus, would cause California to fall into the Pacific Ocean.

Nothing so far has happened, but those who wait for the end to come are always ready with a new prediction.

What, then, can we say about catastrophe? Can we laugh and say the world will not and cannot come to an end? No, for there are ways the whole universe might end and that would mean the end of us.

EXPANDING UNIVERSE

For instance, we know that the universe is expanding. As it expands, the stars of which it is composed consume their fuel and finally can radiate no more. The birth of new stars is no longer possible when all the hydrogen (the basic fuel in the universe) is consumed. The universe will then have run down and if the end for us has not come before, it will surely come then. Still, the general rundown of the universe will not happen for many trillions of years. There are other catastrophes that will come before then.

WEAKENING GRAVITY

Accompanying the expansion of the universe is the possibility of a change in its fundamental laws. Some scientists speculate, for instance, that the force of gravity is slowly weakening as the universe expands. This has the potential of catastrophe for us, except that it would take a billion or more years for the effect to become noticeable, let alone catastrophic.

But then the universe need not expand forever. Under certain conditions (and astronomers are not certain whether those conditions are actually met or not), the expansion would gradually slow down and eventually come to a halt. The universe would then begin to contract again, contracting faster and faster.

FATAL RADIATION

This, however, does not give us a new lease on life, for a contracting universe pushes radiation ahead of itself into a more and more energetic form that would be fatal to all life. However, even if the universe does enter into a contraction cycle, that will not happen for perhaps 25 billion years and there again we are in no immediate danger.

It may be, too, that superimposed on the general expansion of the universe are local contractions brought about by violent events in the history of giant stars and clusters of stars. These contractions may force matter together so densely as to form "black holes" from which nothing can emerge. It may be that black holes already exist and that they continually grow and encroach on matter until everything is gone.

CAUGHT IN A BLACK HOLE?

When will a black hole engulf us? Are we on a collision orbit with one? Astronomers have detected a few objects they suspect might be large sun-sized black holes, but they are so far away that again possible collisions must be billions of years away at the very least.

Some astronomers suspect that black holes can come in all sizes, down to very tiny ones no larger than atoms. There is even a suggestion that the 1908 incident in Siberia, in which a whole forest was leveled without any signs of a meteorite strike, was the result of the passage of such a microblack hole into Siberia, through the body of the Earth and out the Atlantic Ocean.

Black holes are difficult to detect. If they do exist, there is no way of knowing as yet whether any are on the outskirts of our solar system or not.

DYING SUN

Then there's our sun. If we are content to admit the universe won't last forever, surely our sun won't. In fact, our sun should last a far shorter time than the universe does. The sun has now been shining at the expense of its hydrogen fuel for some 5 billion years or so. Eventually, that fuel will run sufficiently low to cause the sun to swell up into a red giant. When that time comes, the Earth will heat up to a point where life on it will not be possible.

This, however, is not expected to happen for some 8 billion years and by that time humankind (if not killed off by some other prior catastrophe) may have moved on to other, younger stars.

Even if the sun remains in its present form, might there not be minor variations, insignificant to the sun itself, but deadly to the Earth? There could be changes in its sunspot activity or in its interior that will cause it to warm slightly or cool slightly--slightly, but enough to boil our oceans or freeze them, and in either case end life on our planet. There are indications, though, that the sun has been fairly stable for billions of years and ought, therefore, to be stable for billions more.

What about the rest of the solar system? Is any part of it going to crash into us?

Velikovsky and his followers believe that in the recent past--only 3500 years ago--Venus, Earth and Mars kept undergoing near-collisions. Rational astronomers find it impossible to take this seriously. There is every indication that the solar system is dynamically stable, that the major planets have kept on their orbits for indefinite millions of years in the past and will continue to do so for indefinite millions of years in the future.

THE METEOROID FEAR

But the solar system is filled with debris--with minor planets (asteroids) of all sizes, from a few that are hundreds of miles across to many thousands that are only a few miles or even a few hundred yards

across. There are uncounted particles ranging in size from a few feet across down to microscopic bits of dust. Some of these minor bodies are close at hand. There are asteroids a mile or two across that have orbits that can occasionally place them within a few million miles of Earth. And there must be bodies smaller still that can come closer--that can even collide with us.

Tiny micro-meteoroids are indeed constantly colliding with Earth by the million and burning up in our atmosphere (the larger ones visible as "shooting stars"). Particularly large meteoroids, from several inches to several feet across, can survive to strike the Earth as "meteorites" and these can cause damage if they score a direct hit on human beings or their works.

The larger the meteor ids, the more damage they do. In primordial times, the craters on the moon, Mars, Mercury and the satellites of Mars and Jupiter were caused by collisions with sizable bodies. One left a crater in Arizona over half a mile across, formed, perhaps, only 10,000 years ago. There are signs of other craters, some even larger, formed longer ago. Nowadays, the collision of a meteoroid capable of forming such a crater might wipe out a city. If it struck an ocean, it might cause a splash that would devastate the coastlines of the world with towering waves of water.

What are the chances of a devastating meteoroid strike? It's hard to say. On the one hand, there are fewer such bodies in space now than ever before since every one that has already struck something else means there is one less to strike us. On the other hand, a strike today on our densely populated, heavily industrialized planet could produce much more damage than in the past when there were fewer people more widely scattered. The chances are, however, that really bad strikes come only tens of thousands of years apart. Perhaps before the next one comes technology will have reached a point where there will be a "meteoroid watch" in space just as there is now an iceberg watch in the North Atlantic.

ANTIMATTER COULD STRIKE

We might compound the disaster by imagining that a meteoroid strike is one of antimatter. Antimatter is composed of particles of a nature opposite to those composing ourselves and the Earth. Antimatter combines instantaneously with matter to give rise to a release of energy (including radioactive radiation) about a hundred times as great, size for size, as that of a nuclear bomb. A small piece of antimatter would therefore do as much damage as a much larger piece of ordinary matter. (Some have speculated that the great 1908 Siberian strike was caused by a small bit of antimatter.)

Antimatter can exist and some astronomers suspect that there may be a whole universe built of it or, within our own universe, whole galaxies of it.

EARTH SLOWING DOWN

Is there any chance that the axis of the Earth may tip over? Something called the law of conservation of angular momentum makes this unlikely. The conservation of angular momentum does not, however, prevent some of the turning effect from being shafted from the Earth to the moon. This means that the moon is slowly drifting away from us and the Earth's rotation is gradually slowing down. As the day lengthens, temperature differences between day and night and between winter and summer would grow more extreme until Earth becomes unfit for life. This change takes place so slowly, however, that it will be many millions of years before its effects will be significant.

The surface of the Earth moves. It is made up of plates that slowly shift. Since the plates are in contact, enormous pressures build up along their boundaries, producing instabilities. It is along these boundaries that volcanoes are formed and that earthquakes take place.

Ordinarily, volcanic eruptions and earthquake tremors occur infrequently and cause only local destruction. But what if there were some effects that could suddenly intensify earthquake and volcanic activity to a catastrophic level?

SOLAR WIND COULD TRIGGER 'QUAKES

There are speculations that the Earth might be affected by the solar wind (particles that shoot out of the sun in all directions) and that the solar wind is, in turn, possibly affected by tidal effects in the sun caused by the planets. Some planetary configurations can cause unusually large tidal effects, possibly leading to a sharp rise in the solar wind. If some fault is on the point of yielding to cause a disastrous earthquake, the changes brought on by the solar wind might just nudge it over the top.

ANOTHER ICE AGE?

What about catastrophes that affect the oceans and atmosphere? What about changes in climate? For instance, every quarter of a billion years, the Earth seems to undergo a period of recurrent ice ages where huge glaciers advance for thousands of years, then retreat for thousands of years. Scientists have speculated on the causes of these periods, but have as yet reached no consensus. We are in such a stage now. Over the last million years, glaciers have advanced and retreated four times.

Are the ice ages over? Perhaps not. The glaciers may someday advance a fifth time. We have survived the previous four advances, but human beings were then few in number and were tribal hunters who could move with the slow advance or retreat of the ice. Now we exist by the

billions and are tied to the land by our farms, mines and cities. A fifth advance would be a catastrophe.

However, the interval between glacial advances is tens, even hundreds, of thousands of years. By the time the glaciers are due to come again, we may have developed the kind of climate control that would prevent them from doing so.

DISASTROUS FLOODS

What about the reverse possibility that the Earth might grow a little warmer causing the glaciers that still exist in Antarctica and Greenland to melt? This would raise the sea level 200 feet and result in disastrous flooding along all the rich and populated coasts of the world. Again, sophisticated climate control might prevent this.

A more subtle danger involves the cosmic-ray particles that steadily bombard the Earth from star explosions and other violent events in the universe. In smashing through living things, these rays can produce harmful mutations that could drive whole species to death and extinction.

DEATH FROM COSMIC RAYS

Much of the cosmic rays are warded off by Earth's magnetic field, which thus keeps the incidence of particles to less-than-harmful levels. But this magnetic field waxes and wanes irregularly for reasons we don't understand. At present, it is waning, and in a couple of thousand years it may pass through a period of centuries in which it is virtually zero. At this point, the incidence of cosmic-ray particles reaching Earth's surface will rise sharply, especially if, at the same time, there are star explosions relatively near our solar system. The extinction, 70 million years ago, of the great dinosaurs might have been caused in this way. Fortunately, the combination of magnetic-field minimum and cosmic-ray maximum is not too likely.

PLAGUED BY PLAGUES

What of danger from other life forms? We no longer fear lions, tigers or other large predators, but what of smaller animals? What of rats that grow ever more vicious and clever? What of insects that grow immune to insecticides? What of epidemic diseases?

In the 14th century, the Black Death struck without warning, killing as many as one-third of all human beings then alive in just a quarter of a century or so. This was the greatest catastrophe ever to strike humankind in recorded history. Many people then thought that the world was coming to an end.

There have been other plagues--cholera, smallpox, typhus, yellow fever--though none as deadly as the Black Death. As late as 1918, a worldwide influenza epidemic killed almost as many people as the Black Death (though the percentage of deaths to total world population was far smaller).

Might another vast epidemic arise and wreak incredible destruction? It's a possibility. A plague, or a growth of vermin, could strike at any time, but modern medical science is also better able to deal with such threats than ever before.

POLLUTED ATMOSPHERE

What then, of human activities? Is humankind itself hastening its own end? Man has, for instance, been burning carbon-containing fuel--wood, coal, oil, gas--at a steadily accelerating rate. All these fuels form carbon dioxide. Some is absorbed by plants and the oceans but not as fast as it is produced. This means the carbon dioxide content of the air is going up--slightly but nevertheless up. Carbon dioxide retains heat, and even a small rise means a warming of the Earth's atmosphere. This may result in the melting of the polar ice caps with unusual speed, flooding the world before we have learned climate control.

In reverse, our industrial civilization is making our atmosphere dustier so that it reflects more sunlight away and cools the Earth slightly--thus making possible a glacial advance in a few centuries, also before we have learned climate control. At present, the two effects seem to be nearly in balance, and humankind is now making an effort to switch to nonfuel energy--geothermal, hydroelectric, nuclear and solar power. With these, we may avoid both dangers of melting ice caps and advancing glaciers.

RADIOACTIVE POISONING

Nuclear sources of energy can produce dangerous radiation, however. In particular, nuclear fission, which we are using now, not only offers a chance of core-meltings that might liberate radioactivity over a large area, but constantly produces radioactive materials that are highly dangerous and that must be kept out of the environment for thousands of years.

The spreading use of nuclear fission powerplants keeps raising the nightmare of death by radioactive fallout for millions, of large sections of the Earth turning radioactive through leakage of stored ash, of the stealing of nuclear fuel by terrorists for use as the ultimate blackmail weapon. The hope is that we will be able to switch to nuclear fusion (not yet shown to be practical), which may lessen the danger of radiation considerably, or to solar energy, which should remove the danger altogether.

On the other hand, warring nations may deliberately poison the Earth with radioactivity by using nuclear explosives in a vast and senseless confrontation that would leave no victors, few survivors and a ruined planet.

DEADLY NEW WAR WEAPONS

The advance of science in other directions may involve catastrophic dangers, too. War weapons need not be nuclear to lead to unimaginable destruction. The use of nerve gases, biological weapons and laser-beam "death rays" may, in the end, prove just as dangerous as atomic bombs.

Even the advances of peacetime have their dangers. Advances in computer technology may lower the role of humanity and make human beings almost useless. Almost any technological advance may produce waste products that dangerously pollute the Earth. Chemical poisons fill the water and the soil. Automobile exhaust and factory smoke fill the air.

SURVIVAL OF THE UNFITTEST

Pollution need not even be material, either. There can be noise pollution, light pollution, heat pollution, microwave pollution. Even the noblest efforts of medicine may be harmful. So many individuals may be allowed to live through the help of advanced medical techniques, some maintain, that the "weak" and "unfit" will flourish, filling the human gene pool with undesirable genes whose catastrophic potentialities may someday make themselves felt.

A rather unusual route to possible catastrophe, revealed only recently, involves the ozone layer. About 15 miles high in the atmosphere are small quantities of ozone, an energetic form of oxygen, that has the property of being opaque to ultraviolet light, thus preventing most of the sun's ultraviolet from reaching the Earth's surface.

KILLER RAYS FROM SPACE

It is suspected that the propellent gases used in aerosol spray cans, highly stable chlorofluorocarbons that remain in the atmosphere indefinitely, may break down ozone molecules into ordinary oxygen. If the ozone layer is destroyed in this way, great amounts of harmful ultraviolet radiation will flood the Earth. Even if man shielded himself from these rays, the probable extinction of many other species of life would so greatly alter the ecological balance of our planet that our own existence would be greatly endangered.

Still, humanity is aware of this possible danger now and may take steps to prevent it.

INCURABLE DISEASES

Another subtle danger arises from recent microbiological experiments involving the alteration of genes in bacteria. There is a possibility that some altered form of microorganism may be capable of causing a disease (cancer, for instance) against which the natural defenses of the body may not work. If such a microorganism escapes, it may be the Black Death all over again, or worse.

Although the chances of such an accident happening are admittedly small, the prospect is still frightening and the people engaged in such work have voluntarily agreed to suspend their experiments until appropriate safety measures can be put into force.

What, then, if nothing happens and humankind just continues to go on as always without any significant catastrophe at all? That, too, can be a catastrophe--perhaps the worst.

Ever since man has been on Earth, his total numbers have increased from century to century (the only exception being the Black Death century). What's more, the increase has itself been proceeding at an increasing rate. As of 1976, the total world population is at the record high figure of 4 billion and the rate of increase is at a record high of 2 per cent a year, which means a doubling of the population in 35 years.

THE REAL DISASTER--FAMINE

By 2012, then, if things continue as they are, the world population will be 8 billion. It doesn't seem likely that 4 billion more mouths can be added to the present world population in only 35 years without widespread famine.

Under planetary famine conditions, the mad rush to extract food from the earth and the sea at all costs, and the drive to make use of any kind of energy, may permanently pollute and damage the Earth's ecological balance in ways a less desperate humanity would never countenance.

As the starving crowds multiply, the despairing attempt to hoard food or to steal from others will break down order and turn human beings into predators against each other. Some nations, in desperation, may not be able to resist pressing the nuclear panic button to force control over other nations. In the end, the pressures will cause the towering but rickety structure of civilization to collapse. This catastrophe we must fear most. All other possible catastrophes may or may not come. If they come, they may not do so for millions or billions of years.

But the horrifying prospect of world famine is real--and close at hand. Unless it is faced quickly and realistically, humanity could experience its greatest catastrophe within half a century. Solving the problem will call for finding new sources of food as well as some form of population control. Not everyone will agree with the latter, but it is vital the matter be given careful consideration--if man is to survive.

Senior Science

Enrichment Modules

A THEORY TODAY

TEACHING HINTS

FOR

A THEORY TODAY

1. This module should take approximately one hour.

2. It is best to introduce the module by having the students do the reading, the vocabulary research, and the Piagetian Experiments. This should take about thirty minutes.

3. Show the film entitled COGNITIVE DEVELOPMENT. A twenty-minute film on Piaget, #153.4 SaskMedia.

4. Have students do the multiple choice test.

5. Students should hand in their work for evaluation.

A THEORY TODAY

Jean Piaget is a present-day scientist. He lives and works in Geneva, Switzerland. His theory is concerned with the development of thought. He believes that an individual progresses from the simple thought of children to the complex thought of adults by passing through maturational stages: From birth to 2 years, Sensori-motor stage; From 2 to 7 years, Pre-operational stage; From 7 to 12 years, Concrete operational stage; and From 12 years upwards (approximately), Formed operational stage.

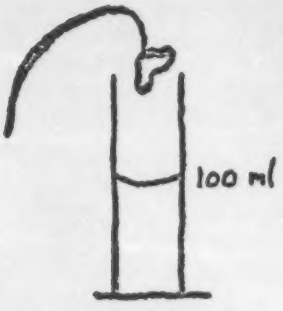
Like all theories in science, Piaget's is not fully accepted today. The main opposing theory, at the present time, is the Behavioural Theory. In the film, Professor Englemann presents a glimpse at this opposing theory. Essentially, the Behavioural Theory suggests that people progressively master more complex sets or rules that reflect how the world is put together and operates. From this view point, competence in thinking at any given age is primarily a function of what the person already knows, and can do.

Vocabulary Research:

egocentric	assimilation	deduction
animistic	accommodation	cognitive
existential		

PIAGETIAN EXPERIMENTS

1. Conservation of Volume



A 250 ml graduated cylinder is filled to the 100 ml level with water. An object on a thread is to be placed into the water. Describe what you would expect to happen to the water level.

2. Syllogisms

(a) Premise #1: All coal is white.

Premise #2: All white coal produces red smoke when burning.

Conclusion: Therefore, when coal burns the smoke is grey.

TRUE OR FALSE

(b) Premise #1: When John gets angry at Mary he hits her.

Premise #2: John is not angry at Mary.

Conclusion: Therefore, John will not hit Mary.

TRUE OR FALSE

MULTIPLE CHOICE TEST

ON

COGNITIVE DEVELOPMENT

1. Which of the following is least likely to be considered a current, major view of cognitive development?

    a. Behavioral
    b. Piagetian
    c. Existential
    d. None of the above

2. From the Piagetian point of view, cognitive development

    a. is sequential
    b. progresses at a constant rate
    c. depends only slightly on experience
    d. all of the above

3. The earliest stage of cognitive development, according to Piaget, is the

    a. concrete operations
    b. preoperational
    c. sensorimotor
    d. formal operations

4. During the period of formal operations

    a. thinking is characterized by egocentrism
    b. there is an emergence of elementary forms of reasoning
    c. object permanence begins to become a foundation of symbolic thought
    d. none of the above

5. The intellectual understanding of conservation

   a. is characteristic of the thinking of four-year-olds
   b. involves assimilation and accommodation
   c. involves thinking about only one of the two or more relevant aspects of a problem
   d. none of the above

6. As shown in the film, the preschool using a curriculum based on Piagetian principles

   a. allows for intrinsic physical activity of children
   b. stresses the importance of social experience in cognitive development
   c. puts an emphasis on providing opportunities to learn in order to aid cognitive development
   d. all of the above

7. From a behavioral-learning viewpoint, cognitive development

   a. depends on what has and has not been learned
   b. depends on cognitive stages as they affect learning
   c. depends on positive reinforcement of "cognitive structures"
   d. all of the above

8. Based on the behavioral-learning teaching ideas expressed in the film, creative thought

   a. is not a reasonable goal of educational experience
   b. is best produced by providing an initial period of "blind experimenting"
   c. initially requires learning a number of fundamental concepts and skills
   d. none of the above

9. In terms of behavioral-learning principles, modifying cognitive development may require

   a. teaching the meaning of instructions
   b. teaching how to respond
   c. teaching a number of appropriate responses
   d. all of the above

10. Which theory do you prefer for intellectual development? Why?

EVALUATION

1. SOME PHILOSOPHIC CONSIDERATIONS

(1) Some Ground Rules For Examining A Science Program[1]

It may be superfluous to say that one cannot examine any science program without some philosophical frame of reference such as:

a) Aims and objectives must be in line with developmental stages of students.

b) The individual is more important than the subject.

c) Concepts are more important than the details that lead to their internalization.

d) Concern for the emotional and valuing development of the student is as important as the development of logic and reason.

e) Students must be educated to participate in and to help shape a world of accelerated interaction and change.

f) Subjects and subject matter at any level cannot be justified in its own merit but only in so far as it makes a positive contribution toward the end of helping young people to understand who they are, their relationship to others, and to their physical and social environment.

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1 PDR Saskatoon, Evaluating Science Programs. A mimeograph, Saskatoon, 1978.

(2) Broad Aims of Science in Saskatchewan[2]

A summary of goal statements would indicate that the main emphasis in "educator intent" is to help students to:

a) develop a spirit of inquiry;
b) provide insight into what science is and how scientists think;
c) emphasize the processes of science (such as: data gathering, data communication, models, seeking relationships in data, hypothesis formation);
d) learn the principles and generalizations of biology, chemistry, and physics;
e) apply the methods of learning in science to real life, to the environment and to other disciplines;
f) learn as much as possible through experimentation;
g) appreciate the limitations of science.

What other broad aims or goals are stated or implied?

(3) Goals of Science Education in Saskatoon[3]

a) TO PROVIDE LEARNING EXPERIENCES IN SCIENCE WHICH LEAD EVERY INDIVIDUAL, REGARDLESS OF HIS INTELLECTUAL CAPACITY, TO A MORE COMPLETE UNDERSTANDING OF HIMSELF, HIS RELATIONSHIP TO OTHERS, AND TO THE ENVIRONMENT IN WHICH HE MUST LIVE AND WORK --

The most fundamental human need of every individual is to understand himself, his relationship to other human beings, and to his cultural and physical environment. Science must be presented in such a way that the student, not science, is the object of instruction. The science experience of young people must be part and parcel of their humanizing experience, subsequently, all efforts directed towards helping students to understand the "nature of nature" must be regarded as a part of a greater task, that of helping students to develop a more complete understanding of the nature of self.

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2 Ibid.

3 Ibid.

b) TO PROVIDE LEARNING EXPERIENCES IN SCIENCE WHICH WILL LEAD STUDENTS FROM AN UNDERSTANDING OF FACTUAL KNOWLEDGE TO AN AWARENESS OF BROAD PREVAILING CONCEPTS WHICH PROVIDE THE BASIS FOR INTERPRETING ALL EXPERIENCE ASSOCIATED WITH NATURAL PHENOMENA --

Within the vast spectrum of scientific knowledge one finds certain prevailing ideas which are so basic to understanding that they constitute the frame of reference for the development and interpretation of new knowledge in every area of scientific endeavor. These same ideas, when "conceptualized" within the minds of students, provide the basis for interpreting and evaluating personal experience associated with natural phenomena.

Science becomes functional when it can be used beyond the context in which it is learned. The extent to which the science experience of the student becomes functional (relevant) depends upon the extent to which he is able to transform temporal and confining bits of factual knowledge into broad conceptual understandings which he can use to explain the "how", the "why", and the "wherefore", of the events that affect his life.

c) TO DEVELOP ATTITUDES AND SKILLS ESSENTIAL IN USING THE "PROCESS OF SCIENCE" AS A MEANS FOR PERSONAL INQUIRY AND PROBLEM SOLVING --

Science, as process, involves the technique of using one's existing knowledge and skills to learn something new. The science program must provide opportunities for all students to develop the skills and attitudes they need to make effective use of the process of science.

Students need to develop various technical investigative skills but more important they need to learn how to define problems clearly, to distinguish between what is known and what needs to be known, and they need experience in making judgments as to what is relevant and reasonable.

Students need to recognize that successful inquiry is characterized by certain personal attitudes such as openmindedness, intellectual honesty, credibility based on fact, curiosity, etc., and they need to learn how to apply these attitudes appropriately in their daily experience.

d) TO DEVELOP AN AWARENESS OF THE IMPACT THAT SCIENCE AND TECHNOLOGY HAS HAD ON SOCIETY IN THE PAST AS WELL AS AN UNDERSTANDING OF THE ROLE THAT THEY MUST CONTINUE TO PLAY IN THE FUTURE --

Modern science and technology have enabled man to effect changes within the environment which have both extended and limited his opportunities for survival. All students, not just those expected to terminate their formal education at the secondary school level, need to become aware of and knowledgeable about the opportunities as well as the problems we face as a result of man's activity within the environment.

The science program must provide learning experiences which will enable students to comprehend the potential of science and technology to affect change within the physical and cultural environment. Students need to know what science can do and what it cannot do. Even more important they need a rational basis for making intelligent and responsible decisions with regard to what science should do and what it should not do for individuals and for society.

e) TO STIMULATE INTEREST IN SCIENCE AND TO ENCOURAGE CAPABLE STUDENTS TO CONSIDER THE POSSIBILITY OF A CAREER IN SCIENCE OR ITS RELATED FIELDS --

Science is a human enterprise and as such requires a continuous influx of gifted and talented individuals. The science program should provide opportunities for students to personally identify with scientists and with the various kinds of work that scientists do in order that they might establish a valid basis for evaluating their interest in and potential for

success in various fields of scientific endeavor.

f) TO PROVIDE THE KIND OF LEARNING EXPERIENCES WHICH WILL ENABLE STUDENTS TO SUCCEED IN POST HIGH SCIENCE COURSES --

A large percentage of the students who continue their formal education after graduation from high school pursue academic careers which require some degree of advanced study in science. Students elect science courses at the secondary school level in anticipation of this eventuality. Students, their parents, and institutions of higher learning expect that the experiences provided in high school science courses will improve a student's chance for success in post high school course work. For these reasons the secondary school science curriculum must be concerned with developing those skills and understandings which are regarded as "pre-requisite" to continued study in the area of science.

2. CONTEXT EVALUATION

The foregoing section upon philosophical consideration looked carefully at science education from three very different points of view: The first, considered science programs in general without regard to nationality or locality; the second, considered science from the provincial point of view; while, the last consideration science programs at the local level -- the Saskatoon viewpoint.

Aside from a few minor adjustments all three points of view tend (quite naturally) to parallel one another. Further more, all three viewpoints appear to substantiate any claims made by this project during the introduction. Certainly, the humanism of science, the impact of science on society, values clarification, and the history of science all seem to be stressed and needed at the provincial and local levels.

The operative word is, of course, the word needed. In context evaluation

a thorough study of the underlying necessities is of paramount importance: Is the program needed? What does the current literature suggest is required? Will the program fit the needs of the students? These (and more) are some kinds of questions which context evaluation must consider, and render a tentative judgment.

Senior Science Enrichment Modules would appear to be very positively received from the context evaluation standpoint.

3. INPUT EVALUATION

Unfortunately, the input evaluation for this project cannot be all inclusive. This not with standing input was received, and utilized, from the following representatives: Saskmedia; Saskatoon Public Library; National Film Board; Saskatoon Public Board of Education; Saskatoon Catholic Board of Education; The Department of Education; University of Saskatchewan; University of Regina; STF Resource Centre; Sunburst Communications; The Center of Humanities Inc.; University of London, England; Saskatchewan Science Teachers Association.

The list, though reasonable long, is not exhaustive, and if any major weakness in the evaluation of the project was found, this particular sector -- input evaluation -- must be classified as relatively weak.

4. PRODUCT EVALUATION

Since Senior Science Enrichment Modules are only approximately fifteen percent of the complete science course, it appeared obvious that a major impact on the course could not be anticipated. Nevertheless, two forms of product evaluation were conducted in order to establish normal educative standards for the project. Both formal and informal evaluation was carried out on the project.

Informal Evaluation

The three members of the project team continuously scrutinized each module during all phases of development. Student input and reaction helped mold each module, so that the finalized versions may be deemed functionally useful. This type of ongoing evaluation, however, has the definite limitation of being insistently internal (that is to say that the rosy blush of self-satisfaction by the team-workers, necessarily it seems, colours everthing in the best light!)

In order to eliminate this rather severe informal limitation three external evaluators were used to identify weakness and to correct our enthusiam: L. Vinish, C. Squires, and T. Antonopolous provided critical comments and corrections which were duly implemented.

The end result from both the internal and external evaluative techniques is a much stronger, more forceful, and functionally reinforced product.

Formal Evaluation

Three instruments were used to try to predict some positive indicators for the quality of the course: A Subject Preference Surveys,
A Student Opinionaire,
and An Objectives Grild

I. Subject Preference Survey

This instrument was devised by the PDR Department of Saskatoon Board of Education. In our evaluation it was used with two classes of students -- one class which had taken the modules as part of their regular course, and one class which had not taken the modules.

The results are shown in table 1:

Table 1: Subject Preference Data

Subject	Number of Students in Module Class						Number of Students in Non - Module Class					
	0	1	2	3	4	5	0	1	2	3	4	5
English	5	7	8	5	2	2	6	6	8	5	3	3
Home Economics or Industrial Arts	3	4	3	4	8	7	2	4	6	8	6	5
Mathematics	2	7	5	3	6	6	1	7	6	5	5	7
Physical Education	4	5	4	6	7	3	5	7	4	8	5	2
Science	0	6	7	5	3	8	1	8	7	6	4	5
Social Study	5	6	7	3	5	3	4	9	5	4	7	2

As may be seen from the data table, student preference for science was slightly better for the module-class than for the non-module class. However, when analyzed for significance (Glass and Stanley, 1970), it was found that the difference was not significant at the .05 level.

II. Student Opinionaire

This instrument was designed by the PDR Department of the Saskatoon Board of Education. Essentially it tries to identify the students' attitude towards science (an Ss score), and the students' perceptions about the science teacher (a Ps score).

The results are shown in table 2:

Table 2: Student Opinionaire Result

	Module Class	Non-Module Class
Number of Students	29	31
Students Attitude Towards Science Score	19	18
Students Perception About Teacher Score	62	54

The Ps score for the Module Class was significant at the .05 level. The Ss score was not significant.

III. An Objectives Grid

As a final evaluative measure an objectives grid was designed to determine the extent of coverage of each project module with the stated objectives in the introduction. Table 3 lists the results (see next page):

In sum, the product evaluation consisting of both formal and informal procedures would seem to at least tentatively, suggest that the project sould be positively received. And as a final very positive comment, the students response to a "Yes" or "No" selection to the question: "Did you feel that the SENIOR SCIENCE ENRICHMENT MODULES were worthwhile?" (n = 157). Only 1.3% responded negatively, 4.5%were blank, and a resounding 94.2% were affirmative.

Table 3: Objectives Grid

MODULES	OBJECTIVES					
	Enrichment Dimension B	Inter-Relationship	Values Clarification	Science Procedures	Historical	Relevance
Group Dynamics	x	x	x	x		x
The Value of Science	x	x	x	x		x
The Lebon Prize	x	x	x	x	x	x
Dr. Stuffy	x	x	x	x		x
The Nuclear Debate	x	x	x			x
Herzberg' Lecture	x	x		x	x	x
Life Boat Ethics	x	x	x	x		x
Early Science	x	x	x	x	x	x
Plato Aristotle Ptolemy	x	x	x	x	x	x
Copernicus	x	x	x	x	x	x
Galileo	x	x	x	x	x	x
Newton	x	x	x	x	x	x
Relativity	x	x	x	x	x	x
Twenty Ways The World Could End	x	x	x			x
A Theory Today	x	x	x	x		x

APPENDICES

1. Subject Preference Survey

2. Student Opinionaire

SUBJECT PREFERENCE SURVEY

School: _____ Male: _____

Grade: _____ Female: _____

Directions:

A. This is a survey of your preferences for school subjects. Each subject is listed several times, but in each case it is combined with one other subject. For each pair, underline the subject you like best.

Make a choice for a subject in each pair even though you may think you like each subject well. Work quietly.

1.	(A) English	(B) Physical Education
2.	(A) Science	(B) Social Studies
3.	(A) Mathematics	(B) Social Studies
4.	(A) Home Economics OR Industrial Arts	(B) Social Studies
5.	(A) English	(B) Home Economics OR Industrial Arts
6.	(A) English	(B) Science
7.	(A) Home Economics OR Industrial Arts	(B) Physical Education
8.	(A) Physical Education	(B) Science
9.	(A) Mathematics	(B) Home Economics OR Industrial Arts
10.	(A) Mathematics	(B) Science
11.	(A) English	(B) Social Studies
12.	(A) Mathematics	(B) Physical Education
13.	(A) Home Economics OR Industrial Arts	(B) Science
14.	(A) Physical Education	(B) Social Studies
15.	(A) English	(B) Mathematics

FOR OFFICE USE ONLY:

English ___ Physical Education ___

Home Economics or Industrial Arts ___ Science ___

Mathematics ___ Social Studies ___

SUBJECT PREFERENCE TALLY SHEET

School: _____ Grade: ____

Number Who Wrote: ____

	FOR TALLY MARKS						NUMBER OF STUDENTS					
	0	1	2	3	4	5	0	1	2	3	4	5
ENGLISH												
HOME ECONOMICS OR INDUSTRIAL ARTS												
MATHEMATICS												
PHYSICAL EDUCATION												
SCIENCE												
SOCIAL STUDIES												

STUDENT OPINIONNAIRE

Below are several statements related to your study of science. Read each statement and consider five possible reactions to each statement. The five responses are:

"I strongly agree" - SA
"I agree" - A
"I am undecided" - U
"I disagree" - D
"I strongly disagree" - SD

Please mark an "X" directly over the letter in the appropriate column.

Name of School _____

Grade and Form _____

Enrolment ____

Sex: Male ____
Female ____

Ss	Ps

STATEMENTS	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree		
1. I am better able to understand the physical world around me because I take science.	SA	A	U	D	SD		
2. My science teacher shows an interest in knowing me as a person.	SA	A	U	D	SD		
3. I like doing experiments.	SA	A	U	D	SD		
4. Science is one class that I can do without.	SA	A	U	D	SD		
5. I have become more skilled in listening and in interpreting directions as a result of my science.	SA	A	U	D	SD		
6. It is possible, most of the time, to ask my science teachers about difficulties or about topics in which I am interested.	SA	A	U	D	SD		
7. The study of science gives me a better understanding and appreciation of the world around me.	SA	A	U	D	SD		
8. I think that many of the ideas and skills that I have learned in science will be useful to me.	SA	A	U	D	SD		
9. Science is interesting and enjoyable.	SA	A	U	D	SD		
10. Students should not be required to take science.	SA	A	U	D	SD		
11. I believe that my science teacher treats me with fairness and sincerity.	SA	A	U	D	SD		
12. I have had occasion to use what I learned in science in daily life.	SA	A	U	D	SD		
13. Most of the time I find experiments and science problems interesting and challenging.	SA	A	U	D	SD		
14. Almost any subject is more interesting and more useful than science.	SA	A	U	D	SD		
15. By discussion or explanation or by written comments my science teacher is very helpful to me.	SA	A	U	D	SD		
16. I feel that science class helps me to use and to understand mathematics better.	SA	A	U	D	SD		
17. I am pleased that I have an opportunity to take science.	SA	A	U	D	SD		
18. Studying science is a waste of my time.	SA	A	U	D	SD		
19. My science teachers challenge me to plan, to think clearly and to work efficiently.	SA	A	U	D	SD		
20. In today's society it is necessary to have some knowledge of science even though a person's work or interests may not be directly connected to science.	SA	A	U	D	SD		

DIRECTIONS FOR ADMINISTERING

1. In spite of the bias and/or limitation, the opinionnaire should be administered by the teacher who teaches the class. THE SAME PROCEDURE SHOULD BE USED BY ALL FOR CONSISTENCY.

2. Teachers should read the following "Directions to Students":

   (a) The Planning, Development and Research Department of the Saskatoon Board of Education working in conjunction with the principal and staff of _____ collegiate
   (name)
   is seeking your opinions and reaction with respect to your science courses.

   (b) The opinionnaire which you are invited to complete consists of twenty items. Please consider each item carefully and indicate your honest and sincere opinion.

   (c) You will not be identified by name.

   (d) Thank you for your anticipated assistance.

Scoring the Opinionnaire

(1) Place the transparency mask on the answer sheets so that the solid lines match.

(2) Add the total number of points in the five circled questions and write total under Ps near top of the page.

(3) Add the total number of points in the remaining fifteen items and write total under Ss near top of the page.

(4) Compute class average for Ss and Ps. Note that the total scores have no meaning unless they are compared to school or system averages and/or to large and small classes.

The opinionnaire consists of twenty items. Fifteen of the items deal with the student's attitude toward science as an area of study. Five of the items (namely, 2, 6, 11, 15 and 19) are intended to seek the student's perception on the extent of "individualization and personalization" given by their teacher of science.

You will note that some of the items are negative eliciting statements; the points are in reverse order on the transparency marking sheet. The items dealing with perception of the teacher are circled on the scoring mask.

STUDENT OPINIONNAIRE

Below are several statements related to your study of English. Read each statement and consider five possible reactions to each statement. The five responses are:

"I strongly agree" - SA
"I agree" - A
"I am undecided" - U
"I disagree" - D
"I strongly disagree" - SD

Please mark an "X" directly over the letter in the appropriate column.

Name of School _____

Grade and Form _____

Enrolment ____

STATEMENTS	SA	A	U	D	SD	Ss	Ps
	5	4	3	2	1		
	(5)	(4)	(3)	(2)	(1)		
	5	4	3	2	1		
	1	2	3	4	5		
	5	4	3	2	1		
	(5)	(4)	(3)	(2)	(1)		
	5	4	3	2	1		
	5	4	3	2	1		
	5	4	3	2	1		
	1	2	3	4	5		
	(5)	(4)	(3)	(2)	(1)		
	5	4	3	2	1		
	5	4	3	2	1		
	1	2	3	4	5		
	(5)	(4)	(3)	(2)	(1)		
	5	4	3	2	1		
	5	4	3	2	1		
	1	2	3	4	5		
	(5)	(4)	(3)	(2)	(1)		
	5	4	3	2	1		

Ss - Attitude Toward Science Score

Ps - Perceptions About The Science Teacher